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of
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NO. 168

LANCASTER QUADRANGLE

GEOLOGY AND MINERAL RESOURCES

Surveyed in cooperation with the U. S. Geological Survey

By

ANNA I. JONAS
Pennsylvania Topographic and Geologic Survey

and

GEORGE W. STOSE
U. S. Geological Survey

DEPARTMENT OF INTERNAL AFFAIRS
JAS. F. WOODWARD, *Secretary*
TOPOGRAPHIC AND GEOLOGIC SURVEY
GEORGE H. ASHLEY, *State Geologist*
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LETTER OF TRANSMITTAL.

James F. Woodward, Secretary,
Department of Internal Affairs.

Sir:

There is transmitted herewith a report on the Geology and Mineral Resources of the Lancaster Quadrangle, to form part No. 168 of the Geologic Atlas of Pennsylvania. The field and office preparation of this report is the result of cooperation between the State Survey and the United States Geological Survey. The joint authors are authorities on the geology of the Piedmont Province. Dr. Anna I. Jonas is a geologist in the employ of Pennsylvania who has been doing detailed geologic mapping in southeastern Pennsylvania for several years, and George W. Stose has been a geologist of the U. S. Geological Survey for more than 30 years. Although the actual field work in the quadrangle dates only from 1922, the results embody the experience and conclusions of many years' work in southeastern Pennsylvania and Maryland.

This atlas is part of the detailed geologic map of Pennsylvania. The United States Geological Survey has already published the geology of 35 quadrangles, calling them folios. The State Survey has published four and has two others in press. Work is in progress on 29 other atlases or folios, 19 by the Federal Survey without cooperation, 8 in cooperation between the two Surveys, and 2 by the State Survey without cooperation.

Respectfully submitted,

Geo. H. Ashley

State Geologist.

December 5, 1927.

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Geology and Mineral Resources of the Lancaster Quadrangle, Pennsylvania[1]

By Anna I. Jonas and George W. Stose.

INTRODUCTION.

Location and Area

The Lancaster quadrangle is in southeastern Pennsylvania and covers parts of Lancaster and Lebanon counties. It comprises an area of 234 square miles between parallels 40° and 40° 15′ and meridians 76° 15′ and 76° 30′. The greater part of the area lies in Lancaster County, only the extreme northwestern corner belonging to Lebanon County. (See fig. 1 and Pl. I.)

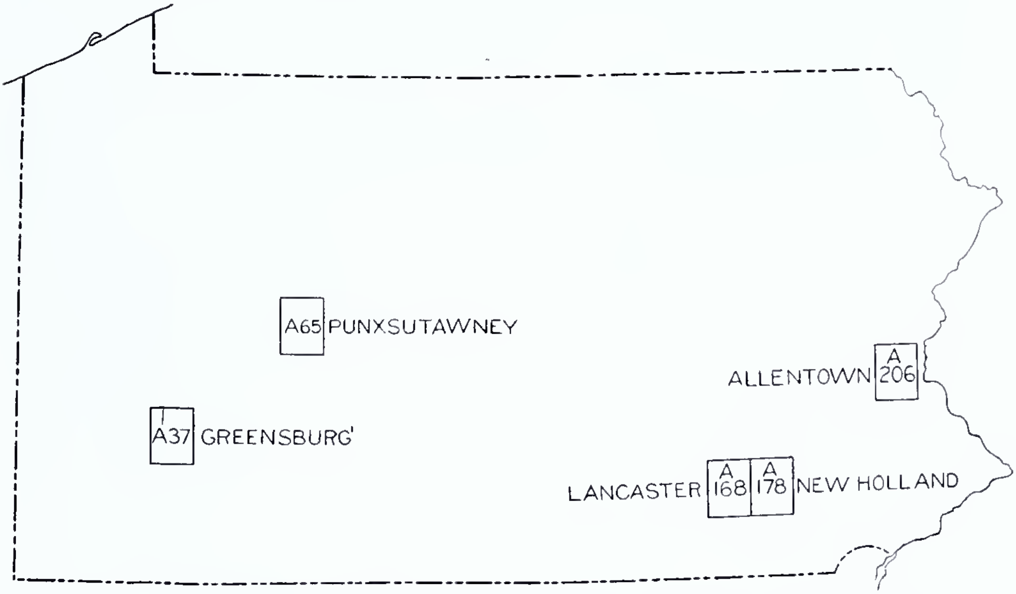

Fig. 1. Index map of Pennsylvania, showing atlases published by the State Survey.

Lancaster, the city from which the quadrangle is named, has a population of over 54,000. Columbia, which lies partly in the southwest corner of the quadrangle, has a population of about 11,000. Lititz, Manheim, and Mount Joy, which are towns of 2,000 to 3,500, are the only other places of over 1,000 inhabitants.

The Philadelphia division of the Pennsylvania Railroad, which is part of the main line between Philadelphia and Pittsburgh, crosses the southern part of the area, running northwestward through Landisville and Mount Joy on its way to Harrisburg and the west. It passes just north of Lancaster by a cut-off which diverts certain through trains from that city, while the remainder of the through and local trains go south into and through Lancaster, rejoining the main tracks northwest of the city. A site for a new station in the northern part of the city has been selected by the Pennsylvania Railroad, and when the station is built the present station and tracks in the city will be removed. Another line of the Pennsylvania Railroad extends west from Lancaster to Columbia and York. It is a branch of the old Northern Central Railroad, now a part of the Pennsylvania System, whose main line connects Baltimore and Harrisburg. Formerly the main line of the Pennsylvania Railroad ran from Lancaster to Columbia and thence up Susquehanna River through Marietta to Middletown, but the shorter present route passes just north of Lancaster and runs northwest through Mount Joy and Elizabethtown. Lancaster is the terminus of the New Holland branch of the Pennsylvania Railroad, which runs eastward to Honeybrook. A freight line of the Pennsylvania Railroad connects Quarryville with Lancaster. The Lancaster branch of the Philadelphia & Reading Railroad connects at Lancaster Junction, 3 miles south of Manheim, with the Columbia division, which runs east from Manheim through Lititz to Ephrata and Reading. Manheim is the junction for the Lebanon and Cornwall branch, which runs north through Mount Hope.

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[1] The Lancaster quadrangle was surveyed jointly by G. W. Stose, of the U. S. Geological Survey, and Anna I. Jonas, of the State Survey. This report was prepared by them in cooperation with the Federal Survey and is published by the State Survey as a part of the Atlas of Pennsylvania.

Lancaster is the center of an extensive trolley system about 165 miles in length operated by the Conestoga Traction Co. These trolleys run on a half-hourly or hourly schedule from Penn Square to all the surrounding towns of the county, and several lines extend beyond the county boundaries. They run west to Columbia and Marietta, southwest to Millersville, south to Quarryville, and east to Gap, Atglen, and Coatesville, 30 miles distant. On the north they reach Manheim and Lititz, and on the northeast a line runs to Ephrata and Adamstown with a branch to Terre Hill.

Lancaster is the center also from which the improved highways of the area radiate; they include State, State aid, and county roads. The Lincoln Highway, which connects Philadelphia with the West, passes through Lancaster and Mountville and extends west to Columbia, where it crosses the Susquehanna on the bridge of the Pennsylvania Railroad. This bridge was burned in 1866 to prevent the Confederate Army from advancing toward Philadelphia along this old toll road, then known as the Lancaster Pike and lately renamed the Lincoln Highway. A concrete highway bridge was built across the Susquehanna at Columbia by York and Lancaster Counties in 1930. This road is paved with bituminous macadam. A concrete road of newer construction leads northwest from Lancaster to Mount Joy and thence to Harrisburg. The Quarryville road, built of concrete for part of the distance, extends southward and connects with the Philadelphia-Washington road south of the State line in Maryland. The last toll road in the vicinity of Lancaster, taken over by the State in 1926, extends north to Lititz. It connects by State aid roads eastward to Ephrata with the Downingtown-Harrisburg Highway, which crosses the northeast corner of the Lancaster quadrangle, passing through Elizabeth Furnace Gap on its way to Cornwall. In 1925 the State built the unpaved portion of the Lancaster-Lebanon road from Manheim to the Lebanon County line. The New Holland road, which runs to Reading by way of Ephrata, extends northeast of Lancaster, crossing Conestoga Creek at Binkley. The Marietta pike is now a secondary paved road which extends west of Lancaster through Silver Spring on the north side of Chestnut Hill.

Besides these main highways there are many improved roads made of limestone throughout the Lancaster quadrangle, and these good roads facilitate travel and transportation and add greatly to the prosperity of the region.

Previous Geologic Work.

The first geologic work in the region was done by Rogers in 1858 for the First Geological Survey of Pennsylvania.[1] He describes the Lower Cambrian quartzite series as "Primal sandstone" and the overlying limestones, which he considered equivalent to the Black River and Chazy limestones of the New York section, as "Auroral." The area was resurveyed by the Second Geological Survey and the results are shown on the geologic map of Lancaster County by Frazer,[2] published with the county report in 1880. This report separated "Eozoic" gneiss and schist, chloritic slate, Cambrian quartzite, and "Cambro-Silurian" limestone, slate, hydro-mica schist, and argillite overlain by Mesozoic sandstone and shale with intrusive trap. In 1892 Lesley[3] republished the geology in his summary report. In 1893 Walcott[4] undertook a reconnaissance of the Cambrian rocks between Susquehanna and Delaware rivers and from his studies of that area established the lower part of the limestone series as Lower Cambrian and the underlying *Scolithus*-bearing quartzite series also as Lower Cambrian and not Potsdam (Upper Cambrian) as they had been called by Frazer in 1880 and Lesley in 1892.

Recent Geologic Work.

No further geologic work was done in this area until the present survey was begun by the writers in 1922. They completed the detailed geologic mapping (Plate II) of the Lancaster quadrangle during parts of the field seasons of 1922 to 1926. The names of the formations and a brief description of them were published in 1922 in a preliminary report[1] based on the work of the writers in the Lancaster quadrangle and in adjoining areas to the east, west, and southwest and the work of E. B. Knopf and A. I. Jonas in the McCalls Ferry and Quarryville quadrangles, which lie south of the Lancaster and New Holland quadrangles respectively. This article was followed a year later by a description[2] of the unconformable relations of the Ordovician Conestoga limestone to the older Paleozoic sedimentary rocks in the Lancaster and adjacent areas. The relations of the pre-Cambrian crystalline schists and Paleozoic rocks of Welsh Mountain and the Mine Ridge upland, east and southeast of the Lancaster area, were described in the same year in a discussion of the crystalline schists of Pennsylvania and Maryland.[3]

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[1] Rogers, H. D., Pennsylvania First Geol. Survey, Third Rept., pp. 11-17, 1839.

[2] Frazer, Persifor, Jr., Geology of Lancaster County; Pennsylvania Second Geol. Survey Rept., CCC, 1880.

[3] Lesley, J. P., Pennsylvania Second Geol. Survey Final Rept., vol. 1, 1892.

[4] Walcott, C. D., Cambrian rocks of Pennsylvania: U. S. Geol. Survey Bull. 134, 1896.

In 1926 was published a geologic map of the New Holland quadrangle,[4] adjacent on the east to the Lancaster quadrangle, which was accompanied by a brief geologic description of the rocks of the area and a report on the mineral products.

SURFACE FEATURES.

Surface Forms.

The area comprises in part a rolling lowland with hilly country in the north and north-central part rising to small mountainous ridges at the northern edge and the rugged hills of Chickies, Chestnut, and Manor Hills in the southwestern part. (See Pl. I, in pocket). These divisions are shown on the topographic and geologic maps by the relations of the contour lines, printed in brown, which are closest together in the hilly areas, where the slopes are steepest and the differences in heights are greatest, and farthest apart in the more nearly level country. Each of the spaces between adjacent contour lines represents a difference in altitude of 20 feet, and every fifth contour line is drawn heavier and numbered to indicate altitude in feet above sea level. The contour lines therefore indicate both heights above sea level and steepness of slope. They show also the shapes of the hills and valleys. The topography was surveyed in 1902 by the United States Geological Survey in cooperation with the State of Pennsylvania.

---

[1] Stose, G. W. and Jonas, A. I., The Lower Paleozoic section of southeastern Pennsylvania: Washington Acad. Sci. Jour., vol. 12, No. 15, Sept. 19, 1922.

[2] Stose, G. W., and Jonas, A. I., Ordovician overlap in the Piedmont province of Pennsylvania and Maryland: Geol. Soc. America Bull., vol. 34, pp. 507-524, September 1923.

[3] Knopf, E. B., and Jonas, A. I., Stratigraphy of the crystalline schists of Pennsylvania and Maryland: Am. Jour. Sci. 5th series vol. 1, pp. 40-61, January, 1923.

[4] Jonas, A. I., and Stose, G. W., Geology and mineral resources of the New Holland quadrangle, Pennsylvania: Pennsylvania Geol. Survey, 4th ser., No. 178, pp. 1-39, 1926.

Altitude of the region.

The highest part of the area is Elizabeth Furnace Hill, west of the gap of Hammer Creek, in the northern part of the quadrangle. The highest point on this ridge is 1200 feet above sea level, 80 feet higher than Governor Dick Hill, 4 miles west of it. These hills extend almost due east, and east of Hammer Creek they pass northeastward out of the quadrangle. They are bordered on the south by lower hills northwest and south of Manheim, which have altitudes between 500 and 600 feet; a southern line of these lower hills forms Kissel Hill. The combined belt of higher and lower hills forms east-west ridges which separate Lebanon and Lancaster valleys.

Another range of hills with altitudes from 500 to 600 feet, known as Chickies and Chestnut hills, extends from Susquehanna River eastward toward Lancaster. The Fruitville hills, north of Lancaster, are an eastward continuation of Chestnut Hill at a somewhat lower altitude. Southwest of Mountville is another line of hills, called the Manor Hills, which extend to the river with an altitude of 500 to 600 feet. The rest of the area is a rolling lowland with an average summit level of 400 feet. This lowland comprises the fertile Lititz, Mount Joy, and Lancaster valleys. The streams have cut valleys about 150 feet deep in this lowland, and Conestoga Creek has reduced the valley surface to 200 feet above sea level at the southern edge of the quadrangle. This is the altitude also of the valley of Susquehanna River at Washingtonboro.

The summits of Elizabeth Furnace Hill, Chestnut Hill, and the Fruitville hills are for the most part wooded with small trees and low, thick undergrowth. The rest of the area comprises well-cleared farming lands, which, owing to the fertility of the soil, the mild and moist climate, and the skill of the farmers, form part of one of the greatest agricultural sections of the United States, locally called "the garden spot of America."

Drainage.

Conestoga Creek, which drains more than one-third of Lancaster County, flows through the southeast corner of the Lancaster quadrangle in a meandering course, on its way to Susquehanna River at Safe Harbor, 7 miles southeast of Washingtonboro. Two of its larger tributaries flow across the quadrangle. Hammer Creek, which heads north of Elizabeth Furnace Hill in Lebanon County, flows southeastward across the northeast corner of the quadrangle into Cocalico Creek, a tributary of the Conestoga. Little Conestoga Creek heads in the hills south of Manheim and flows southward across the quadrangle, passing out of it before joining the Conestoga. Chickies Creek and its main tributary Little Chickies Creek drain the western part of the quadrangle. They unite a mile north of Chickies, where they enter Susquehanna River. This river crosses the southwest corner of the Lancaster quadrangle and forms the boundary between York and Lancaster counties.

THE ROCKS.

The Lancaster quadrangle contains rocks of both sedimentary and igneous origin. The sedimentary rocks consist of conglomerate,* sandstone, shale, and limestone. Some of these rocks have been hardened by heat and pressure and by the addition of cementing material, have been recrystallized into quartzite, slate, phyllite, and crystalline limestone or marble. Indurated and altered rocks of this type belong to the Cambrian and Ordovician systems and cover five-sixths of the surface area. Most of these rocks are limestone, which forms the chief mineral product of the region. The younger Triassic sedimentary rocks, which cover the northern sixth of the area, have been little altered since their formation and consist of slightly compacted conglomerate, sandstone, and shale. (See Fig. 2.).†

The igneous rocks are represented chiefly by Triassic diabase, which is the youngest rock in the area. The diabase was intruded between Triassic sedimentary beds as sheets or sills and was forced into long vertical fissures, forming dikes, which are now exposed at the surface by erosion and removal of the overlying rocks. A few small dikes of pegmatite of Paleozoic age also occur in the quadrangle.

General character of outcrops. The sedimentary rocks were deposited in seas or lakes in a nearly horizontal position, but at the present time none of them lie in this position. The least disturbed rocks are the Triassic formations, which have been tilted gently northwestward but are not folded; the older rocks of the area, belonging to the Cambrian and Ordovician systems, are in most places steeply inclined and are folded into long, wide troughs or synclines and narrower arches or anticlines, which trend south of west. In the softer rocks the pressure that produced the folding has given rise also to a secondary structure called cleavage, which has partly obscured the bedding and is inclined at various angles to it. The rocks have not only been folded but have been dislocated from their normal position by faults, so that beds are repeated in outcrop at some places and concealed or missing at others.

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*Some of these words are defined in the Glossary at the end of the book. (G. H. A.)

†The Pennsylvania Geological Survey has adopted a time scale for use in its publications differing in some points from that used by the U. S. Geological Survey which has been followed by the authors in the preparation of this text. The U. S. Geological Survey divides the rocks into ten systems and geologic time into ten periods. The subdivisions of a system may be called a series, a group, or a formation, according to local circumstances. These periods are recognized as of unequal length. There is a growing practice among recent authors to subdivide some of the larger of these old periods in order that the word period may have more definite and more nearly equivalent meaning. In accordance with this trend the Pennsylvania Survey has followed modern usage and adopted 15 periods in place of 10, naming them from First to Fifteenth, and to the rocks laid down during each of these periods has given 15 system names, following in general the usage of recent authors.

Having adopted names for 15 periods (and systems) the Pennsylvania Survey has next assumed that each period is composed of three approximately equal "epochs," and that any and all rocks laid down during any epoch comprise a "series." Again each epoch has been assumed to be made up of three smaller time units, called "decims," the equivalent rocks being called a "group." A group is made up of "members," (if of different kinds of rocks), or of single beds of rock of moderate thickness. In the above table Ledger dolomite, Kinzers ("formation") member and Vintage dolomite are by the State Survey treated as three members of the Tomstown group, and in strictly State publications would be designated Tomstown (Ledger) dolomites, the group name being used in all names to indicate the stratigraphic positions for there are relatively few groups, but thousands of named members or individually named strata.

The effort of the State Survey has been to set up a standard time scale of large and small units, in which the units of a class are assumed to be of equal length and then as far as possible to fit the rock section to this standard scale. The State Survey retains the term "formation" for any mappable unit of rocks regardless of size. (G. H. A.)

After being folded and broken the rocks were worn down by processes of atmospheric decay and erosion. The harder rocks—the quartzite, slate, conglomerate, and sandstone—are exposed in the hills, which are caused by the resistance of these rocks to erosion. The softer argillaceous rocks and soluble limestone and dolomite, because they are easily worn down and dissolved, occupy the lowlands that form a large part of the Lancaster quadrangle. The lowlands underlain by limestone are covered by a deep, fertile clay soil, which is the residuum of insoluble material in the limestone, and natural outcrops occur chiefly along streams or on the steeper slopes of hills. Chickies and Conestoga creeks and their larger tributaries have cut valleys into bedrock and furnish many good outcrops of the formations which they cross. South of Columbia there are good exposures of the rocks on the left bank of Susquehanna River, which crosses the strike of the formations on its way southeast to Chesapeake Bay.

SEDIMENTARY ROCKS.

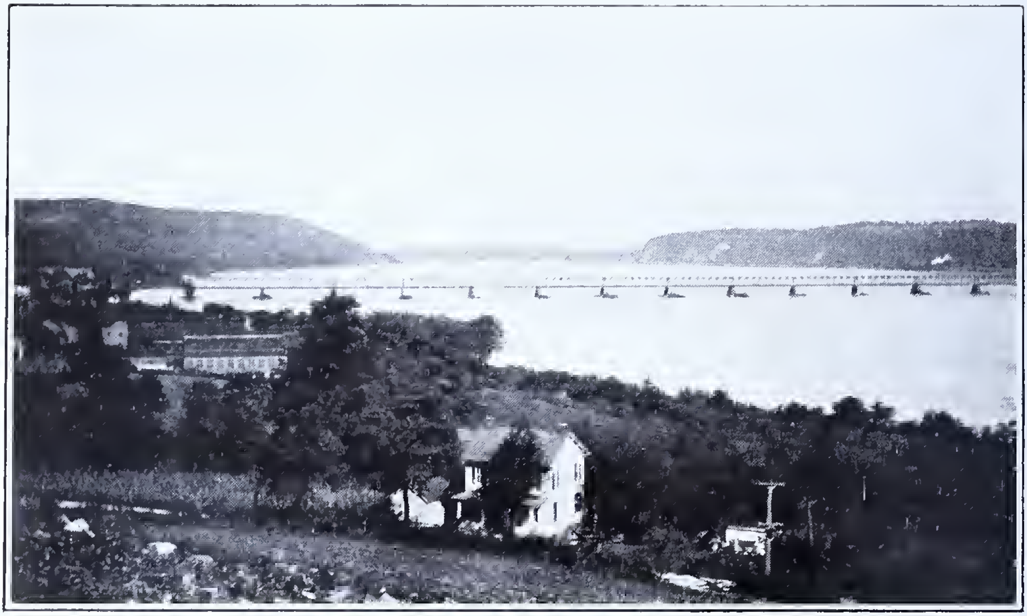
CAMBRIAN SYSTEM.

The Cambrian system is composed of a lower sandy series and an upper limestone series. The sandy series comprises in ascending order the Chickies quartzite with the Hellam conglomerate member at the base, the Harpers phyllite, and the Antietam quartzite, including quartz schist. The limestone series comprises in ascending order the Vintage dolomite, Kinzers formation, Ledger dolomite, Elbrook limestone, and Conococheague limestone.

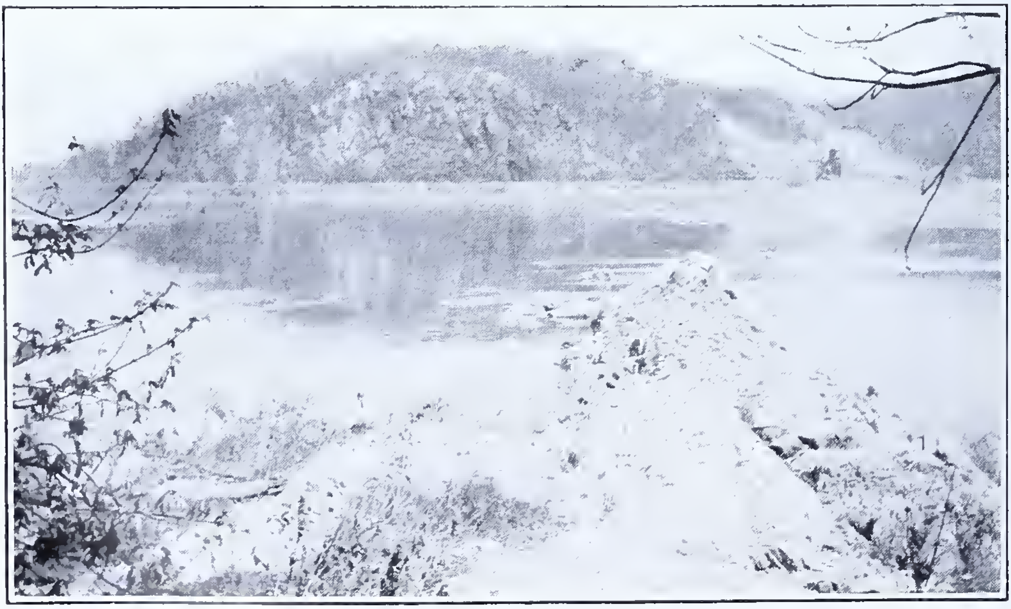
Chickies Quartzite.

Character and thickness. The Chickies quartzite is the oldest formation exposed in the Lancaster quadrangle. Its basal member, the Hellam conglomerate, which is the base of the Cambrian system, is not brought to the surface in the quadrangle but is exposed 3 miles to the west, in the Hellam Hills, west of Susquehanna River. Because of its hardness and resistance to erosion the Chickies quartzite forms the summits of Chestnut Hill, Chickies Hill, and the Manor Hills. It is a thick-bedded, light-colored, vitreous quartzite in which the individual

PLATE III



A. Susquehanna River gap above Columbia. Chickies Rock and Chestnut Hill at right in distance, Hellam Point at left.



B. Chickies Rock, an anticline of Chickies quartzite, from Hellam Point, across the Susquehanna.

quartz grains are not noticeable. The upper part of the quartzite is thin-bedded to schistose, with sericite partings and interbedded thin black slate, and contains quartz grains, clear white to blue or milky white. These upper beds disintegrate into fine white clayey sand, which is extensively quarried for building and plaster sand on Chestnut Hill.

At Oyster Point, the east end of the higher part of Chestnut Hill, a quarry exposes about 35 feet of the upper part of the formation, a crumbly white *Scolithus*-bearing, thin-bedded quartzite and quartz schist, with white clay or sericite partings. In an abandoned quarry on top of Chickies Hill, 1 mile east of Kinderhook (see Pl. IV, A) the following detailed section of these upper beds of the formation was measured:

Section of upper part of Chickies quartzite in Kinderhook sand quarry.

	Feet.
Massive white quartzite, somewhat stained red	15
Thin-bedded crumbly *Scolithus*-bearing quartzite stained purple on weathering	8
White to gray thin-bedded crumbly *Scolithus*-bearing quartzite (quarried)	25
Hard vitreous white quartzite with fine glassy quartz grains (too hard to work)	5
White to gray crumbly *Scolithus*-bearing quartzite (quarried)	42
Massive hard white vitreous quartzite, with clear quartz grains (too hard to work)	15
	110

At Chickies Rock, a bold rocky promontory on the Susquehanna just west of the quadrangle (see Pl. III, B), there is exposed in the cliff a thickness of about 170 feet of massive vitreous white quartzite, which contains long, slender *Scolithus* tubes, more plentiful in the upper part.

A sample of quartzite from Chickies Rock, on the Susquehanna, has the following composition:

*Analysis of quartzite from Chickies Rock.**

SiO_2	97.100
Fe_2O_3	1.250
Al_2O_3	1.390
CaO	.179
MgO	.129
	100.148

The *Scolithus* tubes in the quartzite are casts of borings made by worms in the sand on the shores of an ancient sea and filled with sand and hardened, so that they now appear as sand-filled tubes at right angles to the bedding. (See Pl. IV, B).

The basal Hellam conglomerate member, which is not exposed in the Lancaster quadrangle but crops out across Susquehanna River in the

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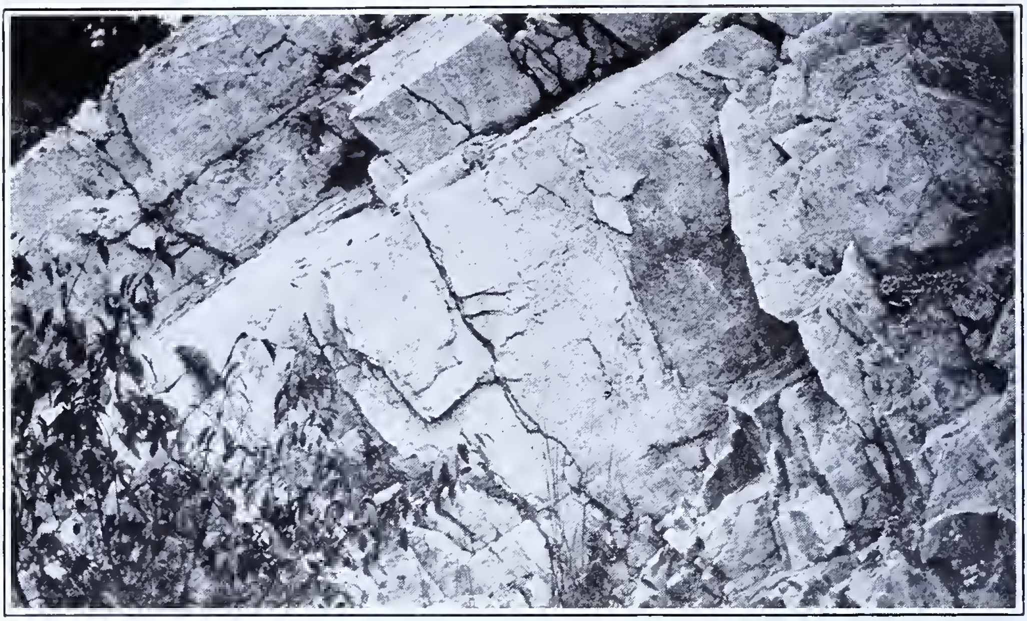
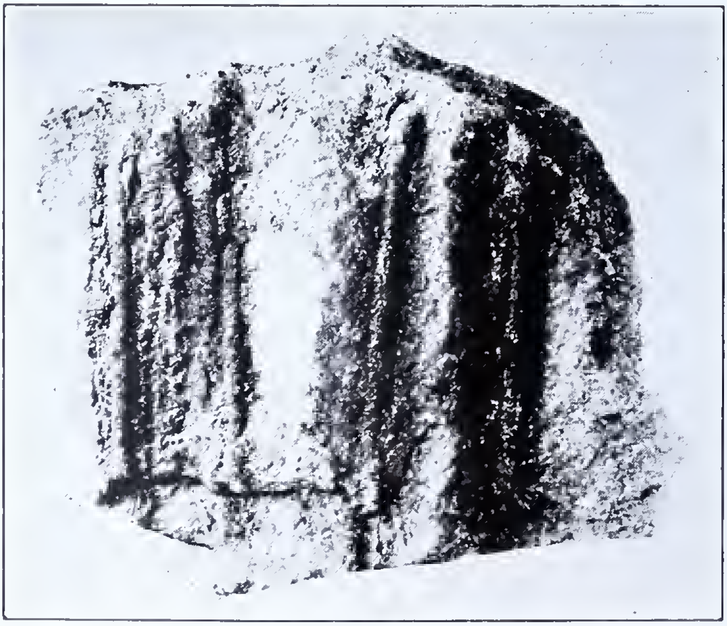
*By A. S. McCreath, Pennsylvania Second Geol. Survey Final Rept., Vol. I, p. 171, 1892.

PLATE IV



A. Massive beds of Chickies quartzite in quarry 1 mile east of Kinderhook.



B. Scolithus tubes in Lower Cambrian quartzite.

higher ridges of the Hellam Hills, is a grainy quartzite containing clear, glassy blue quartz grains and pink feldspar fragments, and pebble beds interbedded with thin sericitic quartzite and dark shiny slate. In the Hellam Hills this member contains beds of rounded quartz cobbles as large as 10 inches in diameter.

A composite section of the Chickies quartzite, including the basal Hellam conglomerate member, in the Hellam Hills, Chickies Hill, and Chestnut Hill, is as follows:

Composite section of Chickies Quartzite.

		Feet
	Upper part chiefly fine white sericitic quartzite with quartz grains in a quartzose matrix containing some feldspar, interbedded with thin black slate; lower part hard white quartzite; in most places the quartzite is *Scolithus*-bearing throughout	300
Hellam conglomerate member	Coarse sericitic quartzite with blue quartz grains and pebbles and coarse conglomerate at the top	200-500
	Dark blue to black slate and interbedded sericitic greenish quartzite with blue quartz grains and small pebbles of quartz and slate	100
		600-900

The Chickies formation in the Manor Hills, 2 miles south of Columbia, is largely a black shiny fissile slate with many thin quartzite plates and leaves and some thicker quartzite beds. This phase is characteristic of the formation throughout the region south of the Lancaster-Hanover valley, where the term Chickies formation is more appropriate than quartzite and is so used on the geologic map. The rock is well exposed in a series of old quarries along the river bluff, but secondary cleavage obscures the bedding in most places so that the sequence and thickness of the beds cannot be clearly determined. The apparent sequence in descending order seems to be as follows:

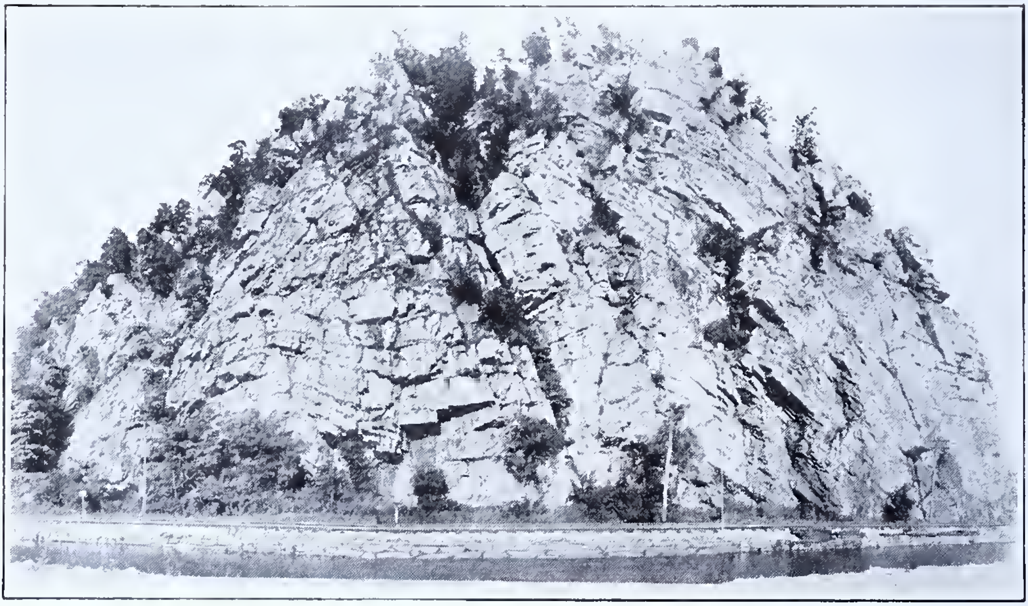
Sequence of beds in the Chickies formation in the Manor Hills.

Thicker quartzite beds and slate.
Thin-bedded quartzite with many dark slate partings.
Black shiny sericitic slate with numerous thin platy leaves of gray to rusty quartzite.
Sandy gray phyllite or sheared quartzite.

The quartzite beds are much thinner than those in the main quartzite belt on Chestnut Hill, and no *Scolithus* tubes were seen in them.

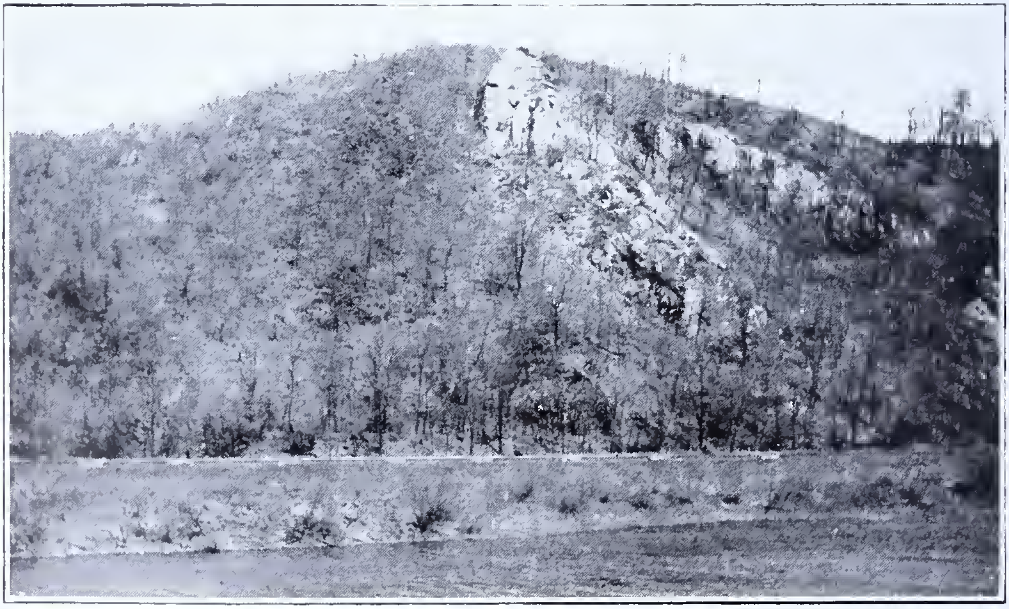
Distribution and structural relations. The Chickies quartzite is exposed in the core of the anticlinal uplifts of Chickies and Chestnut hills. The anticlinal attitude is clearly shown at Chickies Rock (see Pls. III, B and V, A). This anticline of quartzite extends east into the Lancaster quadrangle, where it is composed of several smaller anti-

PLATE V



A. Anticlinal structure of Chickies Rock.

Photograph by C. D. Walcott



B. Small overturned anticline of Chickies quartzite in Harpers phyllite on east side of Susquehanna River south of Chickies Rock.

clines that form ridges and spurs extending eastward to Silver Spring (See Pl. V, B).

The quartzite forms another ridge, disjointed by several cross faults, which marks the crest of Chestnut Hill eastward to the Marietta road. This anticlinal ridge has the Harpers phyllite on both flanks. In the hills north of the Marietta road the quartzite makes no prominent ledges, and the hilltops where the quartzite crops out are cultivated. In the vicinity of Marietta Junction several small up-faulted masses of Chickies quartzite form rock hills in the limestone lowland.

In the Manor Hills the Chickies formation is exposed in the center of the main anticlinal uplift and forms the southern ridge. The north limb of the fold is faulted off by a strike fault.

Age and correlation. The formation was named from the conspicuous cliffs at Chickies Rock, on the Susquehanna, just above Columbia. No fossils except *Scolithus* tubes have been found in it, but it is regarded as of Lower Cambrian age because it is part of a conformable series of sandy rocks the upper beds of which contain fossils of that age.

Harpers Phyllite.

Character and thickness. The Harpers phyllite overlies the Chickies quartzite and is exposed on the flanks of Chestnut Hill and Chickies Hill and in the Manor Hills, south of Columbia. It is a grayish-green quartzose phyllite and dark slate containing some biotite. Because of well-developed cleavage its bedding is observable at few places, and its thickness can not be measured. It is estimated to be about 1,000 feet thick. It breaks up on weathering to shaly fragments, and fresh exposures are seldom seen. Its best exposure is on the top and north side of Chestnut Hill, where dark slate banded with white predominates.

Distribution. The formation occurs on both flanks of Chestnut Hill from Cordelia to Oyster Point. North of the Marietta road it forms the tops of cultivated hills, and its outcrops are hidden by soil. It is exposed in the ravines on the south side of Chickies Hill southeast of Kinderhook. Where mapped between the Chickies and Antietam formations on the south slopes of the Manor Hills it is poorly exposed.

Age and correlation. The formation was named from its outcrops at Harpers Ferry, W. Va., on Potomac River, where it is a shale, being less metamorphosed than the rock in the Lancaster area. No fossils have been found in it, but it is classed as Lower Cambrian because it conformably underlies the Antietam quartzite, which contains fossils of that age. The Harpers formation has been traced from its type locality into Pennsylvania, in South Mountain and along the Pigeon Hills and Hellam Hills into the Lancaster area.

Antietam Quartzite.[*]

Character and thickness. The Harpers phyllite grades upward into the Antietam quartzite, which is the upper formation of the Lower Cambrian sandy series. The Antietam quartzite is light-gray quartzite- and biotite-bearing quartz phyllite, with calcareous ferruginous vitreous granular quartzite at the top. These calcareous beds weather to a dark-red ferruginous soil containing numerous slabby fragments of porous rusty white quartzite, which when split open show on their bedding surfaces rusty molds of the round shell *Obolella* and spines and other fragments of trilobites. This red soil with its characteristic quartzite fragments is an excellent horizon marker for the top of the Lower Cambrian sandy series. The iron content of these upper quartzites was probably originally deposited as carbonate, which is readily soluble in meteoric waters, and when the rock weathers at the surface the iron is concentrated in the form of limonite deposits in the soil. The larger ore deposits, which have been extensively mined, occur along fault zones where underground water circulates most freely. Some of the most productive limonite deposits of this type in the area were located west and southwest of Silver Spring.

The Harpers phyllite grades so gradually into the quartz phillite of the lower part of the Antietam quartzite that it is difficult to decide where to place the boundary, especially where the rocks lie at low angles, as they appear to on the hills north of the Marietta road. The rock fragments in the soil of the cultivated fields on the tops of these hills consist of a sandy phyllite which contains so much quartz that it is classed as Antietam and mapped with the ferruginous quartzite of the well-defined Antietam on the flanks of the hills. On account of this graduation it is difficult to determine the thickness of the Antietam in the Lancaster quadrangle. It is estimated from the dip of the rocks and the width of the outcrop to be about 300 feet. In York County, west of the Susquehanna, the formation is favorably exposed in stream valleys on the south flank of the uplift, where the following section was measured:

Section of Antietam quartzite 1 mile west of Wrightsville, York County, Pa.

	Feet
Impure knotty blue dolomite (Vintage)	
Rusty-weathering quartzite	10
Very sandy dolomite or calcareous quartzite, weathering to a buff sandstone	50
Slabby coarse granular quartzite with rusty fossiliferous partings	50
Banded impure fine-grained quartzite, weathering to light-colored granular blocks, and probably interbedded quartz schist, poorly exposed	150
Sandy gray phyllite or schist (Harpers)	
	260

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[*] Treated by Pennsylvania Geological Survey as a member of Harpers group. (G. H. A.)

South of Columbia the upper ferruginous fossiliferous quartzite so typical of the Antietam is generally present and was the means of the recognition of this formation there. At the Mountville brick quarry these ferruginous beds weather to a ferruginous sandy clay from which an exceptionally handsome maroon brick is made. The lower beds of the Antietam are finely exposed in an old quarry where West Branch of Conestoga Creek cuts through the Mountville Hill anticline. This fresh rock is a hard light-gray fine biotitic quartz phyllite.

Another fresh exposure of the upper beds of the Antietam is in the Susquehanna River bluff on the south flank of the North Manor Hill anticline, just south of Columbia. The section here is as follows:

Section of Antietam quartzite south of Columbia.

	Feet
Light-colored dolomite (Vintage)	
Fine-grained light-gray fossiliferous granular quartzite with glassy grains, containing pyrite, probably derived from original iron carbonate, weathering to rotten ferruginous porous rock	10
Fine-grained gray quartzite, in layers 1 to 4 feet thick, with beds of ferruginous fossiliferous quartzite	30
Well-bedded fine-grained gray quartzite	15
Bluish schistose fine-grained sandstone, stained rusty; bedding indistinct	200±
	255±

Distribution and structural relations. The Antietam quartzite crops out on the south side of Chestnut Hill along its whole length. At the west edge of the quadrangle it forms the south face of the hill north of Columbia, on which a cemetery is located. This band is offset about a mile northeastward, nearly to Cordelia, by a diagonal fault. It makes the lower southern slope of Chestnut Hill to the Marietta highway but this strip is also offset at several places by diagonal faults. It forms most of the east end of Chestnut Hill north of the Marietta highway and the larger hill that extends north of Centerville. A small upfaulted mass makes a hill in the limestone valley near Marietta Junction. An anticline brings up a long, narrow band of the formation in the area of Vintage dolomite south of Silver Spring.

A long, narrow anticlinal mass of the Antietam quartzite forms the Fruitville Hills and is sharply offset at Fruitville by a cross fault. Several seattered small sandstone masses in the Vintage dolomite area to the east are anticlines of the same formation which do not rise so high. They are part of an anticlinal horst, to be described later. Another anticline in a similar anticlinal horst brings the Antietam quartzite to the surface in a short ridge northeast of Binkley.

The prominent hill south of Mountville is a rather symmetrical anticline of the Antietam formation. Another nearly symmetrical anticline forms the north ridge of the Manor Hills just south of Strickler Run. The Antietam formation is again exposed on the south flank of the Manor Hills, offset by a fault, and in an elongated faulted anticline that reaches eastward to Little Conestoga Creek.

Age and correlation. The formation was named from Antietam Creek, near Sharpsburg, Md., where the formation is well exposed in the foothills of Elk Mountain. It has been traced continuously to the northeast end of South Mountain in Pennsylvania and has been observed in the Pigeon Hill and Hellam Hills in the same relations and with the same character as in the Lancaster quadrangle. The fossil shell *Obolella* and spines and fragments of trilobites have been found in the upper ferruginous beds in the Fruitville Hills and at many other places. On the south slope of the Hellam Hills in York County, just west of the Susquehanna, Walcott[1] collected fossils identified as *Camarella minor, Obolella,* cf. *crassa,* and many fragments of *Olenellus thompsoni* (Hall). These fossils are of Lower Cambrian age.

Vintage Dolomite.[2]

Character and thickness. The calcareous quartzite at the top of the Antietam grades upward through a white sericitic siliceous dolomite into gray dolomite typical of the overlying Vintage dolomite, which is the lowest of the Paleozoic limestones. The Vintage dolomite comprises in general a heavy-bedded gray dolomite, which weathers to a whitish chalky surface, and a knotty dark-blue dolomite with hard argillaceous beds and partings. Some of the beds are sparkling gray to blue, mottled with lighter or darker siliceous and calcareous blebs that stand out in relief on the weathered surfaces. The impure basal beds are a cream-colored to pinkish-white fine grained marble, in places micaceous, which contains sphalerite at one place in the Manor Hills and is a distinctive horizon marker generally recognizable by its lithologic character. The dolomite weathers to a characteristic dark-red or maroon granular soil with few rock exposures. The best exposure of the formation in the region is in the cut of the Pennsylvania Railroad at Vintage, 13 miles southeast of Lancaster, where the following section was measured:

Section in cut of the Pennsylvania Railroad west of Vintage, Pa.

	Feet
Kinzers formation:	
Dark graphitic shale.	
Argillaceous dolomite with dark carbonaceous partings; weathers to earthy rock or tripoli in which fossils are evident ..	7
Vintage dolomite:	
Light-gray massive dolomite without bedding	33
Covered; probably dolomite	100±
Massive sparkling gray-blue mottled dolomite; weathers chalky with siliceous and calcareous blebs in relief	30
Blue dolomite, wavy bedding, with micaceous partings	25
Thin micaceous shale	5
Blue argillaceous dolomite; weathers to thin slivers, with some blue massive dolomite bands	15
Granular dolomite, light gray mottled with blue, in 5-foot beds	35

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[1] Walcott, C. D., Cambrian rocks of Pennsylvania: U. S. Geol. Surv. Bull. 134, p. 15, 1896.

[2] This and the Kinzers formations and Ledger dolomite are treated as "members" of the Tomstown group by the State Survey. (G. H. A.)

Dense darker-blue massive dolomite with some granular blebs and argillaceous partings; weathers chalky	100
Light and dark mottled dolomite	35
Gray massive dolomite with wavy partings and granular blebs	150±
Largely covered; probably dolomite; dark glistening dolomite, in part thin-bedded, near base	200±
	728±

A section of the Vintage dolomite measured south of Emigsville, York County, showed a total thickness of 620 feet. Estimates of the thickness of the Vintage dolomite in several sections in the south-central part of the Lancaster area range from 500 to 676 feet. South of Columbia it is much thinner, and on the south flank of the Manor Hills anticline it is only 250 feet thick, as shown in the following section:

Section on South flank of Manor Hills anticline.

	Feet
Black calcareous shale (Conestoga limestone).	
Blue knotty dolomite	10±
Concealed	80±
Very massive dolomite	20
Knotty dolomite, thin-bedded in lower part, and containing sphalerite (zinc sulphide) in bottom layers	140
Granular calcareous fossiliferous quartzite containing pyrite (iron sulphide) in top layers (Antietam quartzite)	
	250±

The iron and zinc sulphides were probably derived from carbonates originally deposited with the sediments.

Distribution. The Vintage dolomite makes a narrow band, more or less disjointed by faulting, along the south foot of Chestnut Hill from Columbia to its east end, northwest of Rohrerstown. The band swings northward around the plunging end of the Chestnut Hill anticline and makes a belt of somewhat greater width around the northern part of Chestnut Hill to Marietta Junction. It underlies most of the lowland between Silver Spring and Chestnut Hill. Several small areas of the Vintage dolomite occur in the triangular fault blocks northwest of Marietta Junction. The dolomite forms most of the lowland between the hills of Antietam quartzite and those composed of the Kinzers formation in the Fruitville anticlinal horst, which extends from a point near Landisville to Landis Valley. Another area of the formation surrounds the hill of Antietam sandstone near Binkley. A belt of Vintage dolomite surrounds the anticlinal hill of Antietam quartzite south of Mountville, and very narrow bands of the formation with few outcrops surround the other anticlinal hills of the Antietam and older formations in the Manor Hills.

Age and correlation. The formation was named from Vintage, a town on the Pennsylvania Railroad southeast of Lancaster, where the character of the dolomite and its relations to the overlying Kinzers formation are clearly shown. It has not yielded fossils in the Lancaster area but contains many fossils, chiefly trilobites, bachiopods, and cystids, in the Middletown quadrangle, just west of the Lancaster area. The Lower Cambrian age of these fossils was recognized by Walcott[1] in 1896, after a reconnaissance of the valley areas of Lancaster and York counties, and they are further described by him in more recent reports.[2] In his early report he identified the following fossils from the lower part of the formation;

Iphidea bella
Salterella conica
Protypus senectus Billings
Solenopleura sp.
Zacanthoides sp.
Olenellus sp.

The upper part of the Vintage dolomite, just beneath the impure dolomite at the base of the Kinzers formation, is more fossiliferous and yielded the following forms, as listed in Walcott's early report:

Kutorgina sp.
Billingsella festinata Billings
Olenellus thompsoni
Cystidean plates
Salterella conica
Protypus senectus Billings

The last-named genus has been renamed *Corynexochus* with subgenus *Bonnia*. It is specially characteristic of the basal limy beds of the overlying Kinzers.

Kinzers formation.

Character and thickness. The Vintage dolomite grades up into the Kinzers formation, which makes narrow ridges separating the valleys underlain by the Vintage from the valley areas of Ledger dolomite. The most conspicuous ridges of the formation are those which extend through Bamford and Mountville. The formation consists of hackly blue shale with thin earthy dolomite which weathers ribbed and white spotted nodular marble (called in the field "leopard rock") with blue to buff wavy dolomite partings that weather to a peculiar knotted wavy structure (See Pl. VI).

At the base there are thin beds of impure dolomite which grades into the underlying Vintage dolomite and weathers to a fossiliferous yellow earthy rock or tripoli. A section measured in the cut of the Pennsylvania Railroad at Kinzers, 13 miles southeast of Lancaster, is as follows:

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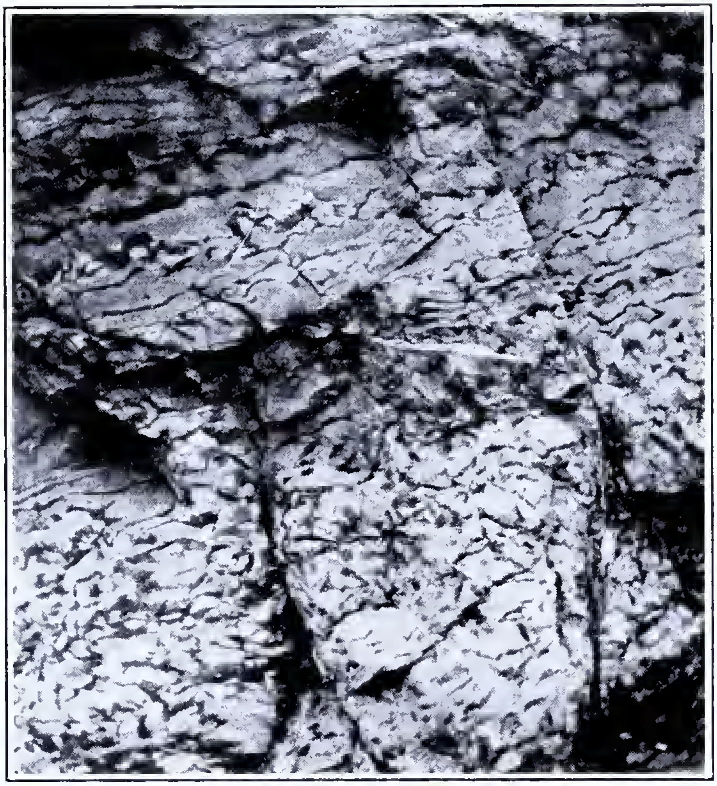
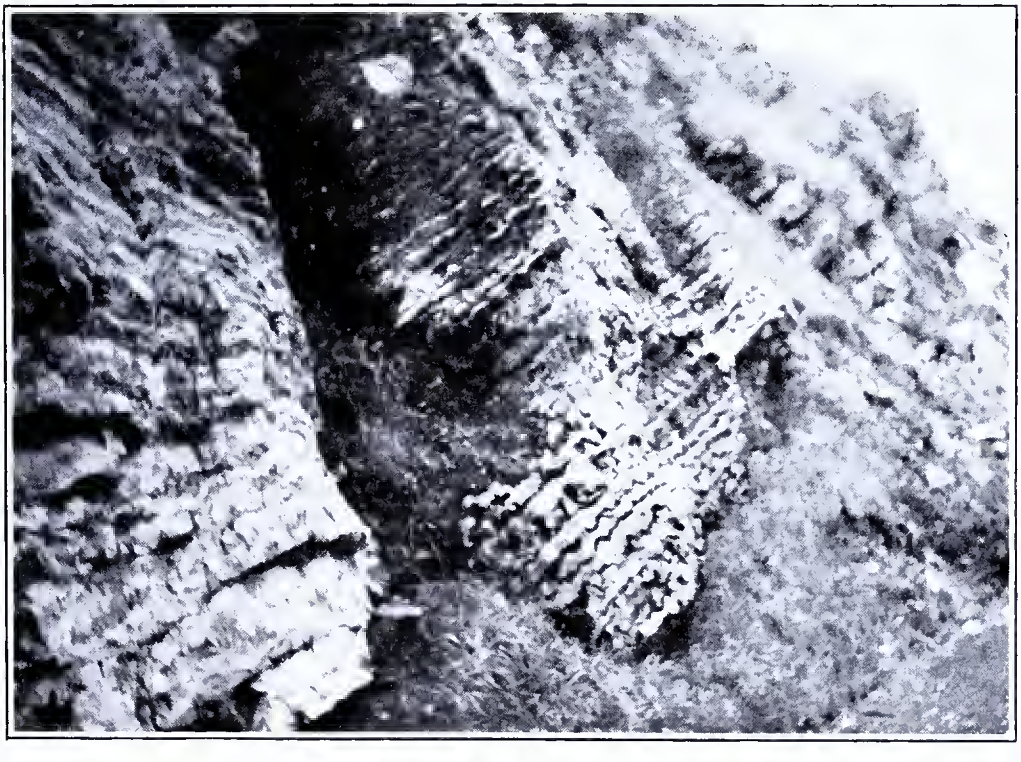
[1] Walcott, C. D., Cambrian rocks of Pennsylvania: U. S. Geol. Survey Bull. 134, p. 19, 1896.

[2] Walcott, C. D., Smithsonian Misc. Coll., vols. 53, 57, 64, and Cambrian geology and paleontology, vols. 1-3.

PLATE VI



A. Banded and spotted limestone of the Kinzers formation, Pennsylvania Railroad cut at Kinzers.



B. Wavy banded limestone of Kinzers formation weathered in relief, Pennsylvania Railroad cut at Kinzers.

Section of Kinzers formation at Kinzers, Pa.

	Feet
Dark-blue limestone with wavy partings	10
Thick light-gray dolomite	12
Dark-blue limestone with wavy partings	6
Spotted white nodular marble with buff dolomite partings ("leopard rock")	5-10
Blue limestone with some siliceous banding, slightly wavy	8-10
Highly siliceous banded dark limestone, weathering to buff earthy network	8- 6
Thick-bedded earthy dolomite, weathering to tripoli	2- 4
Spotted white marble with some crenulated dolomite partings ("leopard rock")	8- 6
Wavy banded blue limestone with fine argillaceous laminations at top	10
Dark fissile shale	35-70
Fossiliferous earthy blue dolomite, weathering to buff or orange-colored tripoli with hard brown skin; irregular base with dolomite pebbles	7
Massive light-gray dolomite (Vintage)	
	150±

In the Lancaster quadrangle the blue to gray shale makes up the bulk of the formation and the overlying mottled limestone is in most places thin or absent. Some of these upper distinctive beds are excellently exposed in a small quarry and in the field and road outcrops just north of Rohrerstown. A composite section observed there and at Donnerville is as follows:

Section of Kinzers formation near Rohrerstown, Pa.

	Feet
White impure marble, with siliceous partings; weathers to tough tripoli	20±
Sandy dolomite; weathers to tough, hard porous sandstone	5
Concealed	50±
White spotted dark limestone ("leopard rock")	10
Tough sandy blue dolomite; weathers buff and somewhat ribbed; fossiliferous	20
Dense blue impure limestone, spotted and nodular ("leopard rock")	6
Hard blue slaty limestone; weathers ribbed	15
Concealed; probably shale	50±
Thin knotty crystalline limestone	1
Dark hackly shale	30±
Impure fossiliferous dolomite; weathers to porous sandstone	4
	211±

Distribution. The Kinzers formation makes a line of low knobs and ridges near the foot of the south slope of Chestnut Hill. Northeast of Columbia, where the dips are gentle, the white spotted marble and ribbed impure limestone above the shale are well exposed. Farther east only a thin band of shale has been seen, probably because of steep dips and narrow outcrops. At Mountville the shale makes a rather prominent hill where it lies in a syncline between the Chestnut Hill and Mountville anticlines. A slender band of shale and white spotted marble lies along the north side of the North Manor Hill anticline, following Strickler Run. Northeast of the Marietta road the dips are again gentle and the upper part of the formation makes a wide band around the plunging end of the anticline. West of Bamford, on the north side of the anticline, only a thin band of the shale has been observed. Beyond Marietta Junction the shale on the north side of the anticline is faulted out. The Kinzers formation makes small ridges in the four triangular fault blocks south of Salunga and a larger ridge south of Landisville. Several short hills of shale occur northwest and northeast of Fruitville in the Fruitville anticlinal horst, and longer curving hills of shale lie in the fault block north of Shreiner.

Age and correlation. The formation was named from Kinzers station on the Pennsylvania Railroad, 13 miles southeast of Lancaster. It is the most fossiliferous formation in the area, and the yellow tripoli at the base of the shale is referred to as the "*Corynexochus* zone" because it contains *Corynexochus (Bonnia) senectus* in abundance. It is well exposed in the Donnerville quarry, 1 mile east of Mountville, where it forms the top of the quarry, above massive Vintage dolomite.

Fossils collected from this bed at localities south of Emigsville, in the Middletown quadrangle, listed by Walcott in his 1896 report, are as follows:

Eocystites sp.

Ipidea bella Billings
Unidentified brachiopods
Billingsella festinata Billings

Protypus (Corynexochus (Bonnia)) senectus Billings
Hyolithus americanus Billings
Olenellus thompsoni Hall
Salterella conica

Many of these forms have been collected from these beds at Donnerville, Rohrerstown, Landisville, and other places in the Lancaster quadrangle and identified by Charles Resser. They are correlated with the Lower Cambrian of New York and Vermont.

Trilobites are especially abundant in the shale of the Kinzers formation in the Lancaster quadrangle and westward to York. The Fruitville quarry, south of the Conestoga Traction Co's. track at Fruitville, and the Noah Getz quarry, 1 mile north of Rohrerstown, are noted as fossil localities, and large collections from them have been made by Prof. H. Justin Roddy and Noah Getz. Trilobites are also abundant in the shale in the cultivated fields northwest of Fruitville. The following forms are reported by Walcott[1] from these and other localities of the shale in the Lancaster quadrangle: *Olenellus thompsoni* (Hall), *Paedumias transitans* (formerly called *Olenellus thompsoni) Wanneri walcottanus* (Wanner) (see Pl. VII), *Holmia macer,* and a form of seaweed associated with the trilobites.

A large collection of trilobites was made by Noah Getz from the

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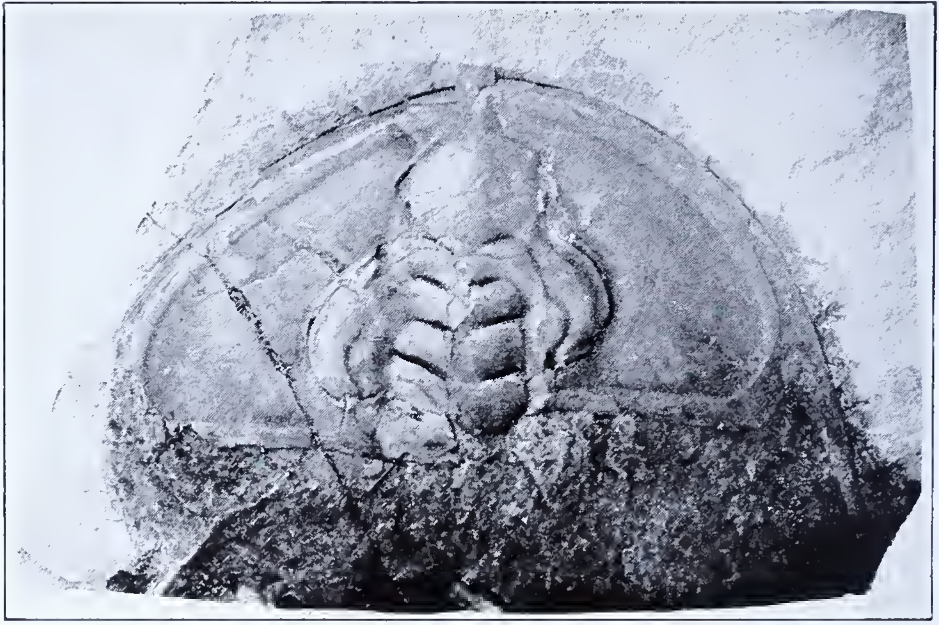
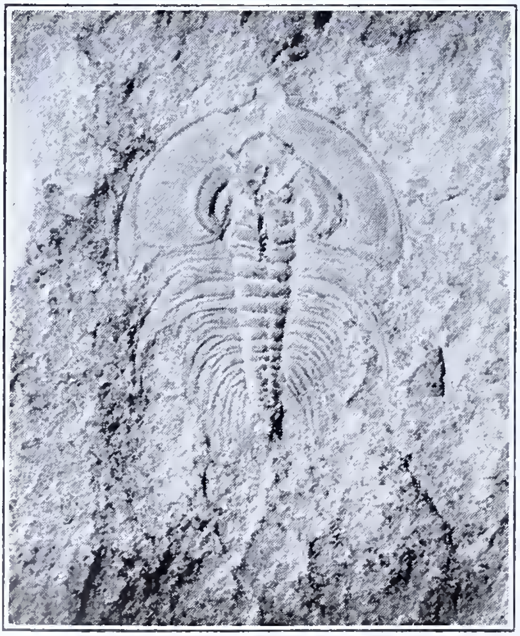
[1] Walcott, C. D., Smithsonian Misc. Coll., vols. 53 and 57; Cambrian geology and paleontology, vol. 1, No. 6, pp. 297, 302, 305, 340, 1910; vol. 2, No. 8, pp. 246, 314, 1912.

PLATE VII



A. Fossil trilobite head from Kinzers formation; Olenellus thompsoni. Natural size.



B. Fossil trilobite; Paedumias transitans, formerly called Olenellus thompsoni. Enlarged x 2.

quarry on his farm, many of which are now in the possession of Yale University. The *Wanneria walcottanus* (Wanner) three miles northwest of Lancaster, described by Walcott, also a cephalon from the Rohrerstown locality and thoracic segments and hypostoma from near York, have a reticulated surface which is similar to the type of surface of *Olenellus reticulatus* Peach, from northwestern Scotland.

Ledger Dolomite.

Character and thickness. The Ledger dolomite, which overlies the Kinzers formation, is the upper formation of the Lower Cambrian calcareous series. It is in general a massive-bedded sparkling white or light-gray coarse-grained dolomite, in part mottled by fine dark-gray spots. A few beds are dark gray; others are dark blue; a little is fine grained. In general it is a very pure dolomite, but near the middle there are siliceous or cherty beds which weather to irregular pitted ferruginous chert. It is so massively bedded that bedding planes are seldom seen except in the upper layers, which are thinner and better bedded. It weathers to a dark granular crumbly surface and forms a characteristic deep-red granular clay soil which in places contains rough ferruginous chert.

The dolomite weathers so readily that it is nearly everywhere covered by the deep red soil and has few rock outcrops. Its character is best observed in quarries, such as the Bellemont quarry, 2 miles north of Lancaster, and the Dolomite Products Co. quarry, at Shreiner. Good exposures may also be seen in the railroad cuts south of Dillerville, where some of the rock appears to be nearly a pure calcium limestone. The high-calcium limestone in the large quarries in the vicinity of York and Hanover is in the Ledger formation, and from a study of the rock in these quarries the writers have concluded that the original rock was a pure high-calcium limestone which in most places has been altered to dolomite by the replacement of some of the calcium by magnesium. This accounts for the coarse character of the dolomite and the general lack of bedding planes.

As exposures of the formation are rare, and the bedding of the dolomite difficult to determine, the thickness of the formation can not be measured. It is estimated to be about 1,000 feet.

Distribution. The largest area of the formation in the quadrangle lies just north of Lancaster, where it is about 1½ miles wide. This wide belt extends from the east edge of the quadrangle to Dillerville and thence northward to Fruitville, comprising some of the richest farm land in the quadrangle. The formation also extends eastward on the north side of the Eden syncline nearly to the east edge of the quadrangle. It extends westward in a narrower belt to Landisville, but with some interruptions due to faulting. A small elongated area lies north of Chestnut Hill near Farmdale, and a narrow belt disjointed by faults lies between the line of hills of Kinzers formation and Conestoga limestone south of Chestnut Hill, extending from Rohrerstown to Columbia.

Age and correlation. The formation is named from the village of Ledger, 15 miles east of Lancaster, where the dolomite makes prominent outcrops. The Ledger and Vintage dolomites and the intervening Kinzers formation are equivalent to the Tomstown dolomite of the Cumberland Valley, where fossiliferous shale and characteristic mottled limestones of the Kinzers type are not present but are probably represented by dolomite. No determinable fossils have been found in the Ledger dolomite in the Lancaster area, although sponge-like markings were seen in a quarry at Shreiner. The writers found brachiopods in this formation southwest of Hanover, which were identified as *Nasusia festinata* Billings by Charles Resser and referred by him to the Lower Cambrian. Other fossils apparently from this formation were collected near York by Walcott, who identified them and published the following list in his 1896 report:

Cystidian plates
Eocystites
Sponge, undet.
Microdiscus cf. M. jarkeri Walcott
Olenoides cf. O. marcoui Whitefield
Olenellus sp.
Zacanthoides sp.
Ptychoparia adamsi Billings
Ptychoparia teucer Billings
Agraulos sp.
Protypus (Corynexochus (Bonnia)) senectus Billings
Acrotreta sp.
Agnostus sp.
Bathyuriscus sp.

These are all Lower Cambrian forms.

Elbrook Limestone.

Character and thickness. The Elbrook limestone normally overlies the Ledger dolomite, but in the southern part of the quadrangle it is not exposed above the Ledger because it is overlapped by the Ordovician Conestoga limestone. The Elbrook is in general a finely laminated, very fine-grained dove-colored to light-blue magnesian limestone with some thin argillaceous layers and cream-colored fine-grained marble with white sericitic partings. It weathers to buff-colored shaly limestone and finally breaks up into thin platy fragments of buff tripoli in light sandy soil, contrasting strongly with the red clay soil of the Ledger. It gives rise to low hills that stand above the level of the dolomite lowland. The formation is generally so deeply weathered that the details of its character and thickness can not be determined. Its best exposures in the quadrangle are along Conestoga Creek at Binkley and for a mile to the south. From observed dips and width of outcrop it is estimated to be about 1,000 feet thick.

Distribution. The Elbrook limestone occurs in the Eden syncline in the vicinity of Roseville, Binkley, and Eden; in two areas north of the syncline—one near Fruitville and the other at Hunsecker (just east of this quadrangle); in a long area from Landisville through East Petersburg nearly to Oregon; and in an anticlinal area 1 mile north of Neffsville. In the Marietta anticline, in the western part of the quadrangle and in the adjacent Middletown quadrangle it is not recognizable between the Ledger dolomite and the Conococheague limestone but its apparent absence may be due to a change in lithology, chiefly the appearance of dark limestone and dolomite interbedded with white marble, resembling the Conococheague limestone.

Age and correlation. The Elbrook limestone in the Lancaster quadrangle and adjacent areas has not yielded fossils. It closely resembles in lithologic character the Elbrook limestone of the Cumberland Valley, which has been traced from the type locality in the Chambersburg area to the Lebanon Valley, north of the Lancaster area. It also occupies the same stratigraphic position as the Elbrook, although the underlying purple shale and sandstone of the Waynesboro are not present in the Lancaster area. However, a thin but prominent bed of gray to red calcareous ripple-marked sandstone which lies at the base of the Elbrook in the adjacent New Holland quadrangle and farther east, where in places it forms a prominent ridge, probably represents the Waynesboro formation of the Cumberland Valley. The name Elbrook has therefore been applied to this formation, and its age is assigned to the Middle Cambrian.

Conococheague Limestone.

Character and thickness. The Conococheague limestone overlies the Elbrook limestone without observable unconformity. It is made up of an alternation of impure thick-bedded glistening dark-blue limestone, with bands of black chert, lenticular knotty and impure dolomite, light-gray impure limestone, and white to light-gray fine-grained laminated marble. The dolomitic beds weather rough and knotty, and the argillaceous limestones weather to a banded rock in which siliceous layers stand out in relief as a network. (See Pl. VIII, A.)

A banded calcareous sandstone or chert generally occurs at the base of the formation and gives rise to residual sandstone fragments in the soil. The formation contains thick layers of thick-bedded light-gray fine-grained marble, which are *Cryptozoon* reefs. (See Pl. VIII, B.) There are generally present also thin-bedded wavy limestones probably of related organic origin. Such reef-bearing beds are well exposed on Chickies Creek northwest of Farmdale and in the quarry 1½ miles northwest of Neffsville. The rhythmic occurrence of these reefs, suggesting seasonal growth, is well shown in the following section at this quarry (see also Fig. 3).

PLATE VIII

A. Siliceous banded limestone of the Conococheague near Vogansville, New Holland quadrangle.

B. Cryptozoon reef in Conococheague limestone near Vogansville.

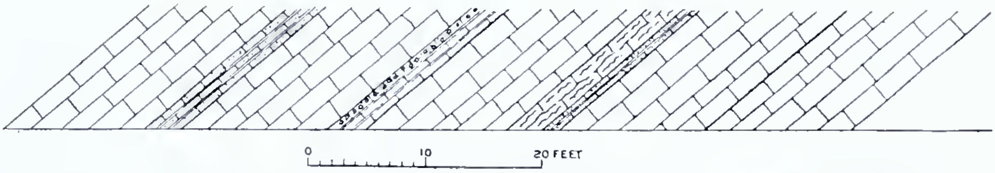


Fig. 3. Section of reef-bearing beds in Conococheague limestone; northwest of Neffsville.

Section of reef-bearing beds in quarry northwest of Neffsville.

	Feet
Pure limestone, *Cryptozoon* reef	8±
Sandy limestone conglomerate weathering to sandstone	2±
Pure light-colored marble, dark at top (probably *Cryptozoon* reef)	8
Black banded limestone; limestone conglomerate and sandy beds at top	2
Pure light-colored marble, *Cryptozoon* reef	8
Thin wavy banded limestone, probably organic laminations	2
Dark banded lenticular limestone	1
Pure dark limestone, *Cryptozoon* reef	8
Pure limestone, *Cryptozoon* reef	8
Rough-weathering dolomite	

The miscellaneous character of the beds composing the formation is well shown in the railroad cut at Salunga, in a quarry beside the Harrisburg road north of Chickies Creek, in quarries and stream cuts on Chickies Creek in the vicinity of Centerville, and by the following detailed section in a quarry in the New Holland quadrangle:

Section showing variable character of Conococheague limestone, Kurtz quarry, 1 mile southwest of Ephrata.

	Feet
Yellow earthy-weathering fine-grained, wavy-bedded magnesian marble, nodular at base	10
Light-gray fine-grained marble, laminated with magnesian layers, weathering buff and finely crinkly	4
White saccharoidal marble	1
Fine-grained magnesian limestone, weathering buff	3
Fine-grained mottled white marble, banded with drab and somewhat magnesian	4
Dark argillaceous fine-grained limestone, weathering with buff banding	3
Shaly magnesian limestone with black carbonaceous seams	2
Dark and light gray banded fine-grained marble, weathering buff banded and ribbed, to earthy buff tripoli	4
White and gray mottled fine-grained marble, weathering cavernous	3
Massive dark dolomite; no bedding planes	8
Light-gray fine-grained marble, mottled with dark gray, in part laminated with earthy layers	6
Massive black dolomite; no bedding planes	8
Thin-bedded dark dolomite	5
Black hackly hard siliceous dolomite, veined with calcite; no bedding planes	20

The formation weathers to light-yellow sandy soil containing many shaly and sandy fragments and white quartz and consequently makes low hills which rise above the limestone lowland. The formation is much folded, and exposures are so poor that the thickness can not be measured, but it is estimated to be about 1,000 feet.

Distribution. The Conococheague limestone covers a large hilly area around Centerville, north of Chestnut Hill, and extends eastward across the quadrangle to Oregon, making the higher land with yellow sandy soil northwest and north of East Petersburg and north of Neffsville. Another wide area is exposed in the Lititz anticline from Limerock to the east edge of the quadrangle. A small area is mapped northwest of Roseville, and another at Eden.

Age and correlation.[*] The formation in this quadrangle in lithologically like the Conococheague limestone of the Cumberland Valley and also contains *Cryptozoon* reefs similar to those in the Cumberland Valley and in Maryland. It has therefore been correlated with the Conococheague limestone.

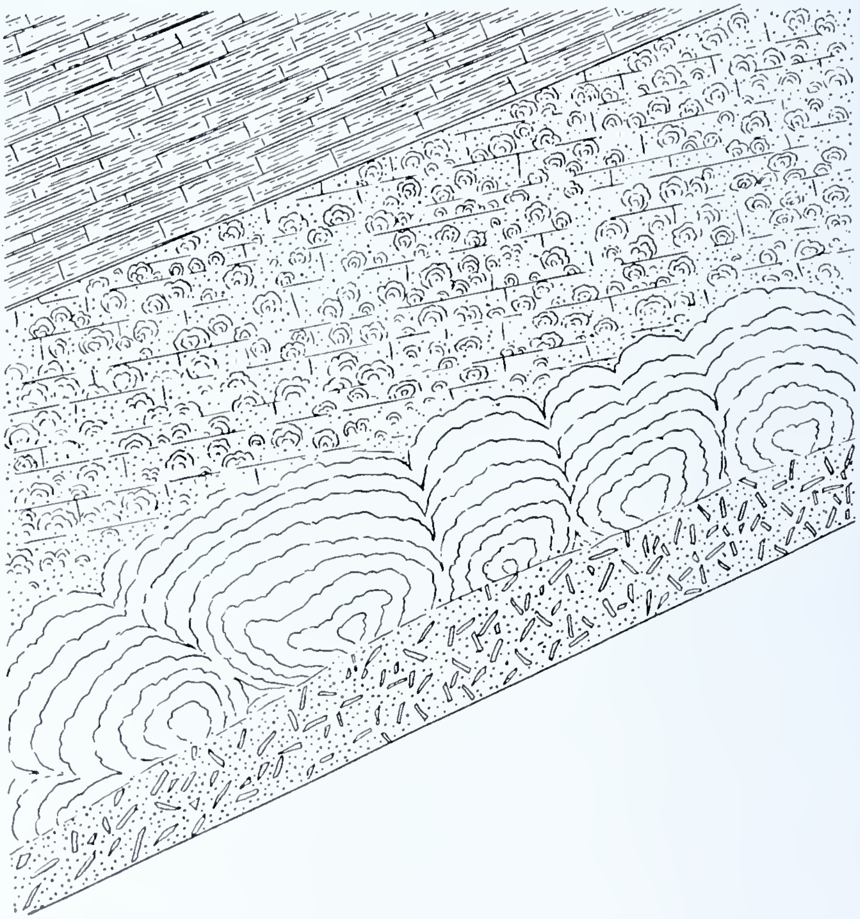


Figure 4. Sketch of a typical reef of cryptozoon from the Conococheague limestone consisting of a 6 inch layer of edgewise limestone conglomerate at the base, 2 foot layer of large cryptozoon heads, 20 inches across the larger head, 2 feet of cross-bedded sandy limestone and oolites full of small cryptozoon heads, and 2 feet at the top of banded dark argillaceous limestone.

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[*] The State Survey has revived the Canadian system as used by Dana, to cover the Chazy, Beekmantown and Ozark, which constitute its upper, middle and lower parts respectively. Conococheague is in the Ozark or Lower Canadian. (G. H. A.)

Cryptozoon reefs are the only identified fossils found in the Conococheague limestone in the Lancaster quadrangle. These forms are large concentrically laminated masses in reef-like aggregations, about 10 feet thick, separated by dark-blue banded dolomite and siliceous oolitic layers. (See Pl. VIII, B and Fig. 4.) They are believed to have been formed by algae. They are apparently of the forms called *Cryptozoon proliferum* and *C. undulatum*, which are referred by E. O. Ulrich to his "lower Ozarkian." The Conococheague limestone is assigned by the United States Geological Survey, on the basis of trilobites and other fossils collected in the Chambersburg area, to the Upper Cambrian, the "Ozarkian" not being recognized by that organization as a separate system.

ORDOVICIAN SYSTEM.

Beekmantown Limestone.*

Character and thickness. The Beekmantown limestone overlies the Conococheague in the northcentral part of the quadrangle. In the main it consists of finely laminated magnesian limestone, light-blue pure limestone with some fine argillaceous banding, and dark-blue lenticular dolomite much broken and recemented by white calcite. There are also beds of white marble near the base. The blue limestone, which has in general a lighter-blue color than the Conococheague limestone, weathers to a pale-blue, light-gray, or chalky white surface on which the fine laminae partings are well brought out. The exposures are too poor to permit the measurement of a detailed section. Its thickness is estimated to be 2,000 feet.

In the vicinity of Mount Joy the lower part of the formation contains a considerable thickness of white saccharoidal high-calcium marble, with sericite on the partings, interbedded with pure light-blue limestone. The upper part of the formation is exposed in numerous quarries in the vicinity of Manheim and west of Clay, where beds of dark dolomite occur above the pure limestone. In the quarry southwest of Manheim the uppermost beds of the formation consist of buff-weathering dark dolomite 20 feet thick, in which fossils of the *Turritoma* zone have been found, underlain by 25 feet of dark and light mottled limestone with magnesian laminations, and this in turn by thick light-blue fossiliferous pure limestone.

South of Sporting Hill the following section of beds at about the same horizon is exposed in a quarry:

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*Assigned by the State Survey to Middle Canadian. (G. H. A.)

Section of part of Beckmantown limestone in Kauffman quarry.

	Feet
Dark-blue and black limestone, weathering finely and irregularly laminated	30
Light-gray mottled with dark-gray limestone, weathering laminated; gastropods in granular limestone at top	30
Mostly dove-colored fine-grained, finely laminated marble, and white and dove-colored spotted limestone	25
Dark limestone banded with ½-inch magnesian layers which weather buff and stand in relief; black nodular flint, weathering yellow, near base	45

The Beekmantown limestone weathers to deep reddish soil with few natural outcrops and underlies a country of low relief between the hills made by the Cocalico shale and the low hills of the Conococheague limestone.

Distribution. The Beekmantown limestone occupies a belt 1 to 2 miles wide across the quadrangle south of the shale ridge that extends from Sporting Hill to Kissel Hill. A branch from this belt forms the lowland around Manheim and eastward to Lititz Run. East of the shale hill at Lexington there is another area of the formation. At the west edge of the quadrangle, north of Mount Joy, the Beekmantown limestone occupies valleys back of the shale front, and west of Sporting Hill there is a small inlier of limestone within the shale area.

Age and correlation. Fossils have been found in the Beekmantown limestone in the Lancaster quadrangle at several places. These fossils came from the upper beds of the formation, just beneath the Cocalico shale. They include species of *Lophospira* and *Eccyliopterus* and the ostracod *Isochilina seelyi* (Whitfield), from the quarry 1 mile southwest of Manheim, and *Maclurites oceanus* (Billings), from a quarry 1 mile south of Sporting Hill. Sections from both these quarries have been given above. These fossils belong to the *Turritoma* zone of the Beekmantown limestone of the Cumberland Valley of southern Pennsylvania and Maryland, described by Stose[1] and Ulrich.[2] A generalized section by Ulrich and Stose of the Beekmantown limestone showing faunal zones in the Cumberland Valley is appended for comparison with that of the Lancaster area:

Section of Beekmantown limestone in Cumberland Valley.

	Feet
Interbedded pure and magnesian fine-grained light-gray limestone; no fossils	400
Thin-bedded argillaceous and pure fossiliferous limestone (*Turritoma* zone)	200
Alternation of pure dove-colored limestone and gray somewhat magnesian limestone; few fossils	375

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[1] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio No. 170, 1908.
[2] Ulrich, E. O., Geol. Soc. America Bull., vol. 22, No. 3, pp. 652-655, 1911.

Blue to dove-colored fossiliferous limestone; chert in upper part (*Ceratopea* zone)	250
Dove-colored to pink and blue pure limestone; porous chert in upper part and oolitic cherty limestone at base (*Cryptozoon steeli* zone in lower part)	800
Pure dove-colored limestone overlain by darker limestone with many thin contorted siliceous and argillaceous bands (Stonehenge limestone member)	570
	2,595

In this section several hundred feet of impure gray magnesian limestone overlies the *Turritoma* zone, which is the uppermost fossiliferous zone of the Beekmantown. These upper beds are absent in the Lancaster area and east of the Lancaster area, where the *Turritoma* zone directly underlies the Cocalico shale. At Oregon, just east of the Lancaster quadrangle, large coiled cephalopods were found by the writers in pure limestone, interbedded with the gastropod-bearing blue limestone near the top of the formation.

The *Ceratopea* zone was not observed in this region, but *Cryptozoon steeli* from the next lower member was observed about 1 mile east of Brownstown in the New Holland quadrangle, and similar wavy structures were seen in the limestone near the base of the Beekmantown on Chickies Creek 1 mile north of Salunga. Specimens of *Ophileta*, found by the writers in the Beekmantown limestone east of Clay, near Goekley in the New Holland quadrangle, were referred to the Nittany formation of central Pennsylvania, which there contains also *Cryptozoon steeli* in its lower part.

The formation is therefore clearly the same as the Beekmantown of Cumberland Valley, which is correlated by fossil contents and lithologic character with the Beekmantown of New York. It is probable also that if sufficient fossils were obtainable from the Beekmantown limestone of the Lancaster quadrangle it could be subdivided into some of the members recognized in the Cumberland Valley west of South Mountain and elsewhere in Pennsylvania.

Cocalico Shale.

Character and thickness. The Cocalico shale overlies the Beekmantown limestone and forms a hilly section south of the red Triassic rocks in the northern part of the Lancaster quadrangle. It is a bluish-black to dark-gray fissile shale which discolors to buff on weathering, especially near the base. It contains beds of fine yellowish-green arkosic sandstone in which there are many glassy quartz grains. Near the base also there are beds of bluish-purple and green shale interbedded with the blue to gray shale. The purple and green shales are more abundant in the northern part of the belt, where they are associated with rust-stained and greenish-white hard vitreous fine-grained sandstone composed of glassy grains of quartz with specks of sedimentary mica. The sandstone is well exposed, apparently in a sharp anticline, overlain by purple and green shale, in the valley of Chickies Creek at Whiteoak, and forms a ridge that extends 3 miles westward. Another belt of green and purple shale and quartzite branches off southwestward and extends to the locality where the shale is covered by Triassic sediments. A third belt of hard quartzite and purple and green shale forms a parallel ridge farther south, which extends eastward past Penryn, trending toward the anticline of Beekmantown limestone east of Brubaker. The hard sandstone occurs only in the northern part of the shale area, and the purple and green shales are better developed and apparently thicker where associated with the sandstone. They, however, occur also in places on the southern border of the shale belt near the base, as northwest of Manheim, west of Sporting Hill, at Kissel Hill, and north of Disston. The thickness of the Cocalico shale can not be determined because of poor outcrops and lack of distinct bedding. It is estimated to be about 2,000 feet.

Distribution. The Cocalico shale forms a belt of hills across the northern part of the quadrangle, just south of the red rocks of the Triassic. This belt has its maximum width of 5 miles west of Manheim and narrows toward the western edge of the quadrangle, where embayments of the Beekmantown limestone restrict the shale to a width of about 2 miles. East of Manheim the shale area divides into three belts; the northern one follows the south side of the Triassic rocks to the east edge of the quadrangle, where it is about 1 mile wide; the central belt branches from the first at Penn and extends southeastward through Brunnerville toward Lititz; the third belt extends east from Sporting Hill to Rothsville, narrowing and breaking up into detached hills of shale between Fairland and Kissel Hill. The known distribution of the purple and green shales and white quartzite near the base is shown on the map and is described under "Character and thickness."

Age and correlation. The Cocalico shale is very sparingly fossiliferous, only a few graptolites having been found in it in the Lancaster quadrangle or elsewhere. The first graptolites found in the shale were collected by the writers at Kissel Hill and near Cocalico Creek 1 mile east of Oregon, in the adjacent New Holland quadrangle, in 1921; others were found in 1923 in the shale east of Denver, 6 miles east of the Lancaster quadrangle. At that time they were considered by Ulrich to be of Normanskill type and the shale to be probably of Chazy age. As the shale was believed to be older than Trenton the name Martinsburg was not applicable, and a new name, Cocalico, was given by the writers,[1] from the creek of that name near which the first fossils were obtained from the shale. Further study by Ulrich has thrown doubt on the earlier identification of these poorly preserved graptolites, but he is still of the opinion that the lower part of the Cocalico shale is probably older than the Martinsburg shale of the main belt.

The lithology of the Cocalico shale and of the Martinsburg east of Harrisburg is strikingly similar. The hard purple and green shales and the hard rust-stained to greenish-white indurated sandstone which occur in the northern part of the Cocalico belt are very similar to beds near the base of the Martinsburg in many small areas of the shale in or south of the Great Valley and especially in the main shale belt in the vicinity of Jonestown, described by the writers in a previous report,[2] in which the relations of these shales are more fully discussed.

These purplish and green shales near Old Line and Penn are mottled with green blebs and contain small angular fragments of quartz, which suggest that they had a tuffaceous origin. Specimens collected near Penn show under the microscope angular fragments of granulated quartz in a ferruginous clay matrix. Although they are much less crystalline than the spotted slates of volcanic origin in the western Piedmont region of Maryland, which are either sheared amygdaloid or tuff, they bear a marked resemblance in color and other features to these volcanic rocks. As is pointed out in the report just referred to, lava flows occur at the base of the Martinsburg shale in the vicinity of Jonestown, north of Lebanon. The occurrence of probably volcanic material in the Cocalico shale is another evidence that the two shales are of approximately the same age.

The Cocalico shale of the Lancaster quadrangle overlies fossiliferous upper Beekmantown limestone wherever fossils have been found in the limestone near the shale, except along the shale-limestone contact east of Brubaker, where there is a narrow band of shaly dark argillaceous limestone that is different from that seen elsewhere. This limestone has therefore been separately mapped and treated as a local member of the Cocalico shale. The section of these beds east of Brubaker is as follows:

Section of Cocalico shale east of Brubaker, Pa.

	Feet
Cocalico shale	
Dark shale	
Thin-bedded to shaly dark argillaceous limestone with black carbonaceous partings; some beds granular and containing fragments of crinoid stems, shells, and trilobites	20
Thin-bedded blue limestone alternating with shaly limestone ..	50±
Concealed interval	
Beekmantown limestone: Thick mottled blue limestone	

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[1] Stose, G. W., and Jonas, A. I., Lower Paleozoic section of southeastern Pennsylvania: Washington Acad. Sci. Jour., vol. 12, No. 15, p. 15, 1922.

[2] Stose, G. W., and Jonas, A. I., Ordovician shale and associated lava in southeastern Pennsylvania: Geol. Soc. America Bull., vol. 38, pp. 505-536, 1927.

Besides crinoid stems *Strophomena* sp. and *Proetus* sp. have been identified from these beds, which are regarded by Ulrich as younger than Beekmantown, probably of early Trenton or Black River age.

In the New Holland quadrangle, east of Denver, dark-blue argillaceous limestone like the Leesport limestone locally underlies the Martinsburg shale and contains fossils of probable lower Trenton age.[1]

Fossil evidence therefore shows that in the Lancaster and adjacent quadrangles the Cocalico shale lies unconformably on the Beekmantown and that it may be lower Trenton or younger, and probably is equivalent to the Martinsburg shale north of Lebanon. The recent finding by one of the writers[1] of graptolites of Normanskill age and of Deep Kill (Canadian) age in the shale north of Harrisburg throws doubt on the age of these shales elsewhere to the east.

At Hopeland, in the northeast corner of the Lancaster quadrangle, the Cocalico shale is separated by only 5 miles of Triassic rocks from the area of Ordovician shale at Schaefferstown, on the south side of the Lebanon Valley. The Schaefferstown area lies on the north side of the normal fault which has dropped down the block of Triassic rocks to the south, and it is quite certain that prior to the deposition of the Triassic sediments the Ordovician shale and other Paleozoic formations of the northern part of the Lancaster quadrangle were continuous northward with those in the Lebanon Valley. Furthermore, the formations of the Lancaster area not only closely resemble lithologically the equivalent formations in the Great Valley but they contain the same fossils.

Conestoga Limestone.

Character and thickness. The Conestoga limestone, a formation also of Ordovician age, is present only in the southern part of the Lancaster quadrangle. It is made up chiefly of thin-bedded dark-blue argillaceous limestone and thicker-bedded blue to light-gray granular limestone with thin argillaceous partings, generally closely plicated (see Pl. IX), with beds of dark graphitic shale or slate and coarse conglomerate or breccia of blue limestone and white marble fragments in a dark argillaceous calcareous matrix near the base of the formation. This limestone conglomerate occurs in beds as much as 10 feet thick, interbedded with slaty blue limestone and dark argillaceous dolomite. The conglomerate is well exposed in the quarries north of the Lancaster City waterworks (see Pl. X) and at the stone quarry east of Columbia, and single beds of conglomerate may be seen at many other places near the base of the formation. A band of black graphitic slate

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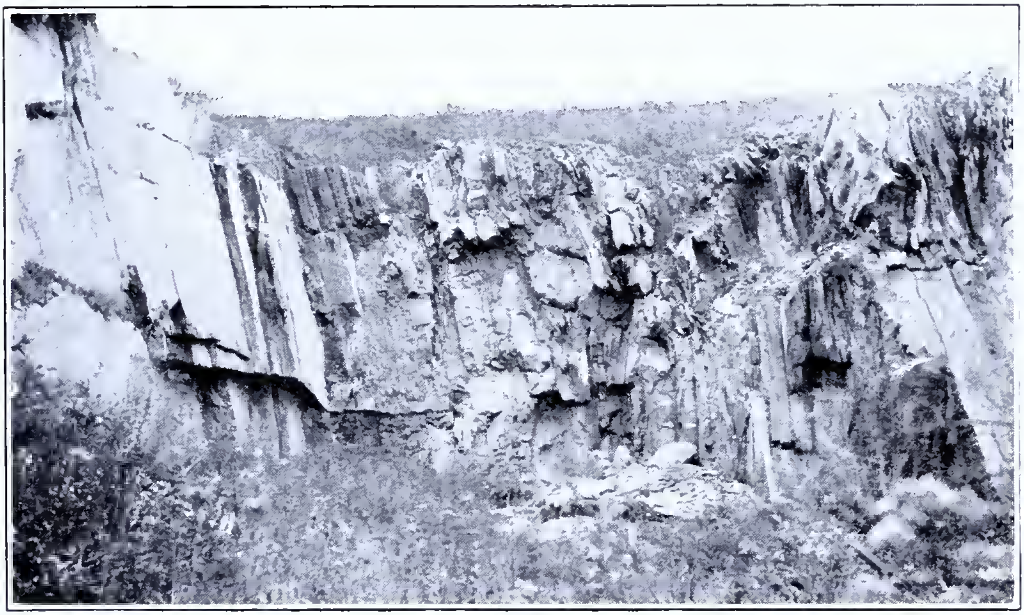
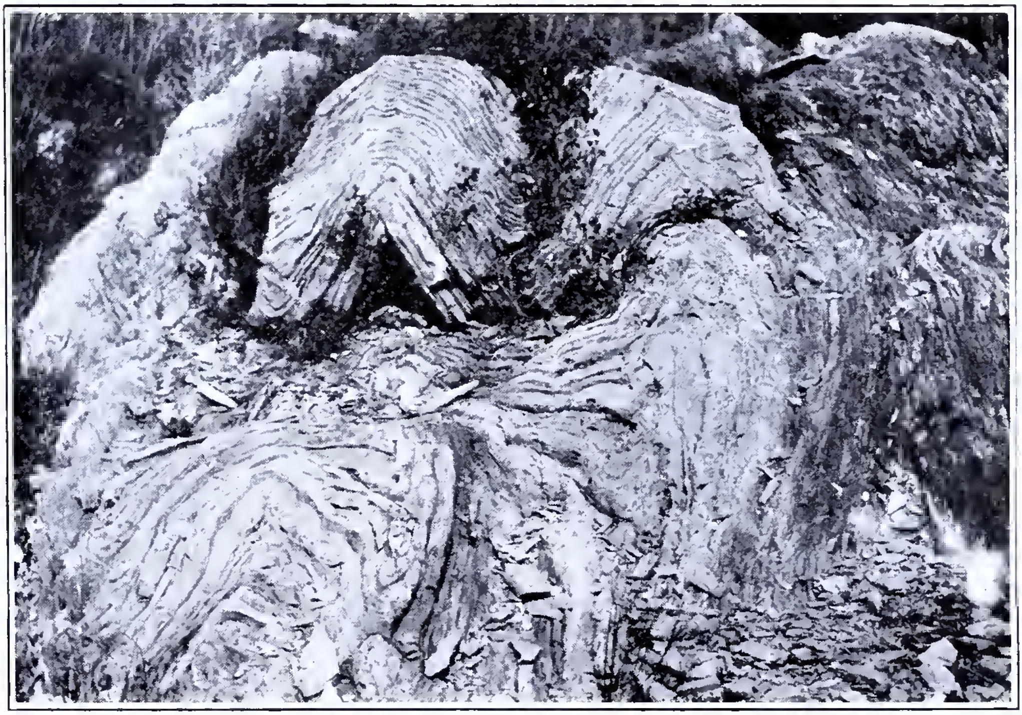
[1] Idem, p. 524.

[1] Stose, G. W., Unconformity at base of Medina sandstone in southeastern Pennsylvania: Geol. Soc. Amer., Abstracts, pp. 30, 31, 1929.

PLATE IX



A. Thin-bedded blue limestone of the Conestoga in quarry at Columbia.



B. Plicated thin-bedded limestone, characteristic of the Conestoga limestone, on Conestoga Creek southeast of Lancaster.

occurs at or near the base in the southwestern part of the quadrangle and has been separately mapped. North of the Manor Hills the basal beds have also been mapped, and are dark-banded buff earthy sandstone and blue hackly shale containing pyrite cubes which weather out leaving rusty holes. This basal member becomes more prominent west of the Susquehanna, where it forms a line of low hills in most places. In the southeastern part of the quadrangle, apparently near the base of the formation, there are thick beds of light-gray granular limestone so full of round quartz grains that the rock weathers to a crumbly sandstone, which is worked for building sand. These beds have also been mapped where observed. The thin-bedded limestones of the formation are generally tightly folded and veined with calcite.

The thickness of the formation can not be determined because of its closely folded character. It is probably more than 1,000 feet thick.

Distribution. The Conestoga limestone covers all of the area south of Lancaster, Rohrerstown, and Donnerville, with small outlying areas north of Lancaster, at Dillerville, and north of Rohrerstown. West of Donnerville it occupies the syncline between the uplifts of Cambrian quartzite in the Manor Hills and Mountville Hill. It also forms the valley around Columbia, where its basal sandy and slaty member is mappable.

Age and relation to other formations. The Conestoga limestone overlies the Ledger dolomite in the eastern part of the quadrangle, and its contact with that formation is excellently exposed in the quarries and rock exposures near the Lancaster City waterworks, northeast of the city. Here the basal conglomerate, made up of masses of white marble as much as 5 feet across, rests on the eroded surface of the Ledger dolomite. (See Pl. X, B.) in places filling narrow solution channels between pinnacles of the bedrock. (See Pl. XI, A.)

At Donnerville the Conestoga limestone overlaps the Kinzers formation onto the underlying Vintage dolomite, and to the southwest it rests chiefly on the Vintage. In the vicinity of Columbia it again overlies Ledger dolomite. This overlapping relation of the Conestoga limestone to the underlying formations had been observed before Ordovician fossils were found in it, and it was thus known to be younger than the Lower Cambrian Ledger dolomite, on which it rests unconformably. This unconformity by overlap has been described in detail by Stose and Jonas.[1]

The Ledger dolomite in the central part of this area is overlain by the Elbrook, Conococheague, and Beekmantown limestones without a structural break in the sequence. The Conestoga limestone does not resemble any of these formations lithologically, and it was therefore considered to be probably of post-Beekmantown age. In 1922 fossils

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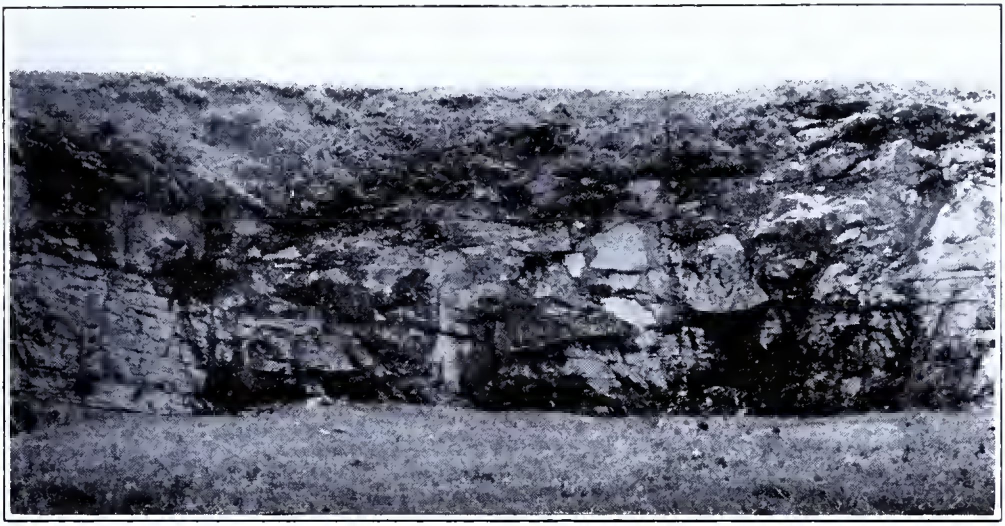
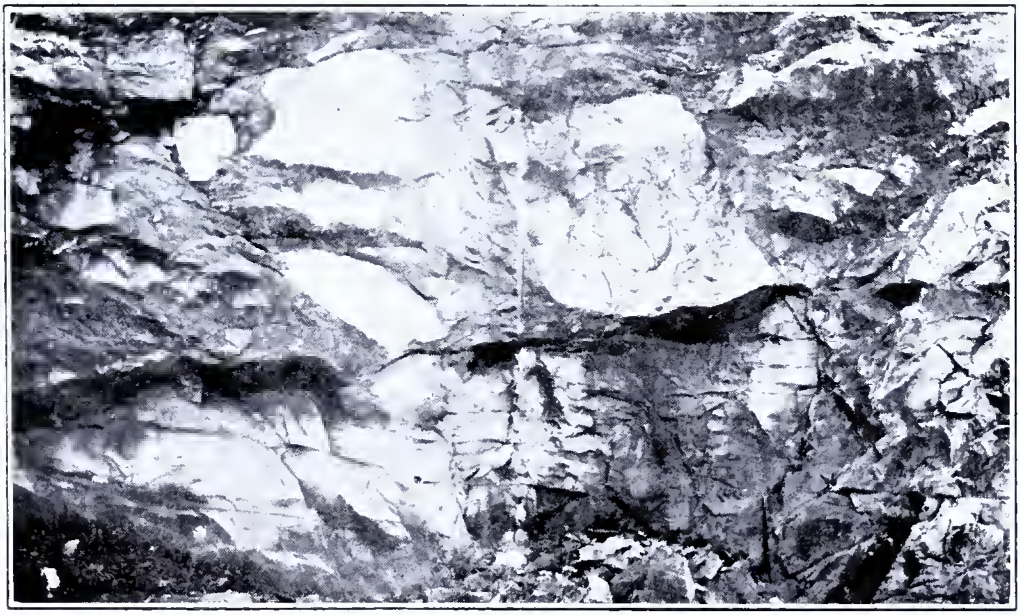
[1] Stose, G. W., and Jonas, A. I., Ordovician overlap in the Piedmont province of Pennsylvania and Maryland: Geol. Soc. America Bull., vol. 34, pp. 510-519, 1923.

PLATE X

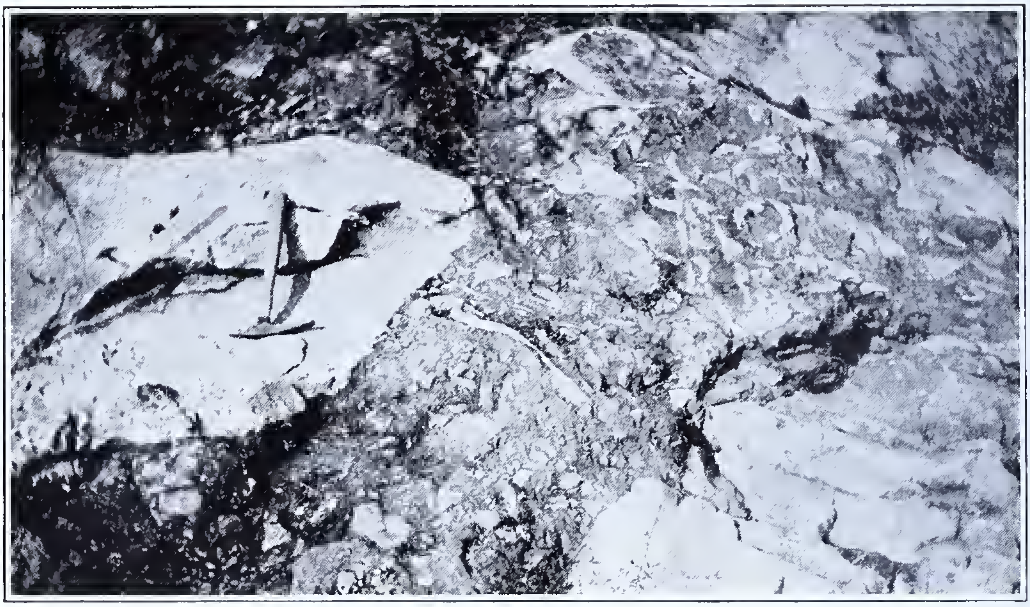


A. Coarse limestone conglomerate at base of Conestoga limestone at old quarry north of Lancaster waterworks.

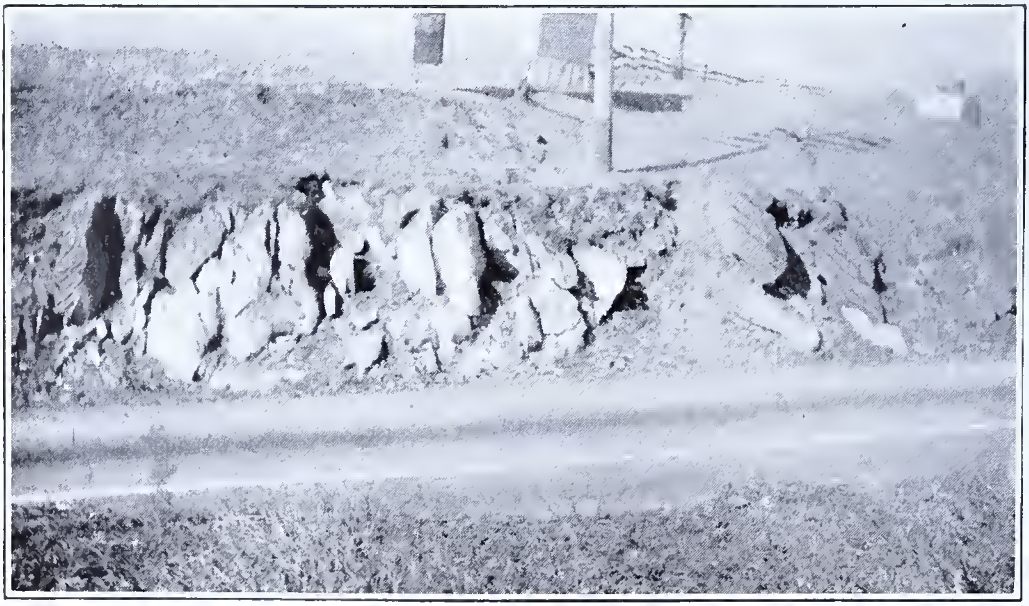


B. Large limestone masses in basal conglomerate of the Conestoga limestone, showing unconformable relation to underlying Ledger dolomite, at old quarry north of Lancaster waterworks.

PLATE XI



A. Conestoga limestone breccia filling a channel in the underlying Ledger dolomite, near Lancaster waterworks.



B. Anticline in Kinzers formation, the plunging east end of Chestnut Hill anticline. Harrisburg road near Dillerville.

were collected in the Conestoga limestone east of York,[1] and the one determinable species, *Strophomena stosei*, is regarded by Bassler as probably Chazy. This form is found also in the Frederick limestone[2] together with *Aciduspis ulrichi*, *Triarthus* sp., and new species of the genera *Reteocrinus?*, *Cameroceras*, and *Isotelus*. This fauna can not be correlated with any known fauna but, according to Bassler, suggests Chazy age.

In 1923 the writers suggested that the Conestoga limestone is approximately equivalent to the Cocalico shale, to the north, which was considered to be also of Chazy age and to represent shale deposition in a more open part of the basin.[3] It has since been recognized that the Cocalico shale is possibly of lower Trenton age and therefore younger than the Conestoga limestone. The Cocalico shale, the Martinsburg shale of the main belt, and the shale of the Steelton area in Dauphin County and other shale areas south of the main belt unconformably overlie[4] limestones ranging in age from Black River down to the Conococheague and probably to the Middle Cambrian Elbrook limestone. The unconformity in that area was apparently post-Black river. The Conestoga limestone in the vicinity of Norristown, Montgomery County, is said to overlie the Beekmantown limestone. In the Quarryville quadrangle, southeast of the Lancaster quadrangle, the Conestoga limestone overlaps onto the Harpers schist. The Frederick limestone, with which the Conestoga is approximately correlated on the basis of contained fossils, unconformably overlies the Beekmantown limestone in the Frederick Valley and also overlaps onto the Antietam quartzite in that part of Maryland. If the fossils of the Conestoga and Frederick limestones are correctly interpreted, those formations are not only older than the Martinsburg shale, but their deposition followed an erosion period earlier than that which preceded the deposition of the Martinsburg shale in the north.

The Conestoga limestone basin lies south of the Welsh Mountain-Chestnut Hill anticline; the basin in which the Cocalico and Martinsburg shales were deposited lies north of that uplift. It is possible that in early Ordovician time this anticline acted as a partial barrier between the two basins, in which are recorded such differences in erosional and depositional history after Beekmantown time; or it may be that the tentative assignment of the lower part of the Conestoga and Frederick limestones to the Chazy epoch is incorrect and that they are of later age and equivalent to the Martinsburg and Cocalico shales; or the Cocalico shale and the Martinsburg shale in this region began earlier than is supposed.

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[1] Idem, p. 520.

[2] Bassler, R. S., Maryland Geol. Survey, Cambrian and Ordovician, p. 117, 1919.

[3] Stose, G. W., and Jonas, A. I., op. cit., p. 524.

[4] Stose, G. W., and Jonas, A. I., Ordovician shale and lava in southeastern Pennsylvania: Geol. Soc. American Bull., vol. 38, pp. 505-536, 1927.

TRIASSIC SYSTEM.

Newark Group.*

In the northern part of the Lancaster quadrangle the Ordovician rocks are overlain unconformably by Triassic sandstone, conglomerate, and shale. These rocks are part of the belt of Triassic rocks called the Newark group, which enters Pennsylvania from New Jersey, crosses Pennsylvania in a southwesterly direction, and extends across Maryland into Virginia. This belt, which has a maximum width of about 30 miles at Delaware River, is only 4 to 5 miles wide in and north of the Lancaster quadrangle, its narrowest point. The rocks are in general red, with beds of light-gray sandstone and conglomerate and light-yellow to greenish arkose. The rocks almost everywhere dip northwestward at an average angle of 35°, varying from 15° to 60°. Two formations have been distinguished in the Lancaster quadrangle and vicinity—a lower arkosic formation called the New Oxford and an upper red shale and sandstone called the Gettysburg. Conglomerates and associated hard sandstones, which generally make ridges, are separately mapped as members of these formations.

New Oxford Formation.†

Character and thickness. The lower formation of the Newark group is characterized by the presence of many beds of arkose. They are generally light-gray or light greenish-yellow crumbly sandstone with many grains of white kaolinized feldspar, glassy quartz, and mica flakes. Some of the beds contain rounded pebbles of quartz and weather to yellowish or light-gray sand and gravel. Interbedded between the arkosic layers are red shale and soft sandstone, which make small valleys between ridges and spurs capped by arkose. The accompanying sketch section across the Triassic rocks north of Penryn (see fig. 5)shows the alternate of red shale and gray sandy rocks. The color banding where these layers cross roads and plowed fields is very noticeable. The rythmic occurrence of rocks of such different character suggests seasonal deposition. Only the most prominent of these beds are illustrated in the section of figure 5. The arkosic beds are extensively dug for building sand in the vicinity of Ephrata, in the New Holland quadrangle, and to some extent near Mastersonville, in the northwestern part of the Lancaster quadrangle. At Hopeland a basal conglomeratic layer composed largely of coarse pebbles of crystalline limestone in a red shale matrix rests on the Cocalico shale.

Near the top of the formation, 1 mile north of Hopeland, in a ravine on the west side of a secondary road, a coal prospect exposes the following section:

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*Newark series of Pennsylvania Geological Survey. (G. H. A.)

†New Oxford group of Pennsylvania Geological Survey. (G. H. A.)

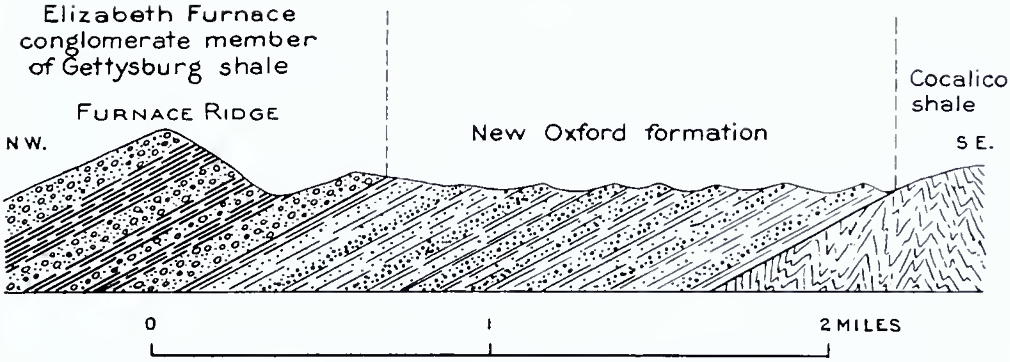

Fig. 5. Sketch section of Triassic rocks north of Penryn, showing alternation of beds of red shale and gray sandstone.

Section at coal prospect north of Hopeland

	Feet
Greenish sandstone containing plant remains with thin coaly films ..	3
Fine crumbly conglomerate	1
Red crumbly shale	10

Similar coal-bearing beds near the top of the formation occur in the railroad cut at Mount Hope. The beds here are thin even-bedded dark-gray carbonaceous arkosic sandstone, containing mica and shale fragments, and a thin carbonaceous conglomerate with carbonized plant remains. Although the finding of these thin coal seams has led to the digging of prospect pits and sinking of shafts, there is no probability that coal seams of workable size occur in the Triassic rocks of this region.

The top of the New Oxford formation in this quadrangle is placed at the bottom of a heavy quartzose conglomerate which forms Elizabeth Furnace Hill and is closely associated with soft red sandstone of the type found in the Gettysburg shale and is therefore included in that formation. West of Mount Hope the conglomerate thins out, owing in part possibly to faulting, and the New Oxford formation in the Lancaster quadrangle is mapped to the base of the great intrusive diabase sill that forms Governor Dick Hill. The thickness determined from width of outcrop and dip of beds is about 4,500 feet.

Distribution and relation. The New Oxford formation makes a belt about 1½ miles wide across the quadrangle from the region north of Hopeland to Elstonville and Mount Hope. West of Elstonville the belt swings southwestward to Mastersonville, beyond which it widens, becoming 3 miles wide in the Middletown quadrangle. The formation rests unconformably on the Cocalico shale throughout the Lancaster quadrangle. The unconformable relation is well shown on the map by the basal beds of the Triassic wrapping around the truncated ends of the anticlinal belt of purple and green shale and white quartzite in the lower part of the Cocalico shale west of Whiteoak and south of Mastersonville.

Age and correlation. No determinable fossils have been found in the New Oxford formation in this area. The few plant remains that were obtained are indeterminable. A few fossil plants and reptile remains have been found in the lower beds of the Newark group in western Lancaster County and in York County, and shells were obtained from the basal beds near New Oxford, Adams County. These establish the upper Triassic age of the rocks. The formation is named from the town of New Oxford, where the Triassic formations have been studied in detail and their thickness determined.[1] The formation has the same lithologic character as the Stockton formation, the lower formation of the Newark group in the eastern part of the State, and these two formations are approximately equivalent, but the Lockatong shale, which overlies the Stockton, thins out near Elverson, Chester County, and has no representative in the Lancaster area.

Gettysburg Shale.

Character and thickness. The Gettysburg shale in the type area is made up chiefly of soft red shale and soft red sandstone. Northeast of the Gettysburg area a lenticular mass of heavy conglomerate, which makes the Conewago Hills, lies within the formation, and a similar lenticular mass of heavy conglomerate and hard sandstone makes up a large part of the Gettysburg formation in the Lancaster quadrangle. This conglomerate, here named the Elizabeth Furnace conglomerate member, begins west of Mount Hope, where it makes low hills. Northeast of Mount Hope it forms the prominent ridge called Elizabeth Furnace Hill, from which it takes its name, and passes northeastward out of the quadrangle. Hammer Creek cuts a gorge through the ridge, and the conglomerate is there seen to have at the top massive hard pebbly sandstone, which caps the high ridge; at the base thinner and less pebbly sandstone, which forms a shoulder and line of knobs and ridges on the south slope; and in the middle scattered hard conglomerates and sandstones. The conglomerate member has a maximum thickness of about 2,500 feet.

The upper beds of the formation consist of soft red sandstone and shale, which lie between the north foot of the conglomerate ridge and a strike fault to the north. A small area of the same soft red sandstone can be seen between the conglomerate and the fault northwest of Mount Hope.

The soft red sandstone and shale of the Gettysburg formation are well shown in the lowland south of Mount Gretna Lake. The formation contains in that area thick beds of red coarser pebbly sandstone which forms low hills, but as they are not prominent they are not separately mapped. These pebbly sandstone beds where indurated by intrusive diabase form higher hills, such as Spring Hill, north of Mount Hope, and part of Governor Dick Hill. The Gettysburg shale above the conglomerate present in the northwest corner of the Lancaster quadrangle is estimated to be about 2,000 feet thick.

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[1] Stose, G. W., U. S. Geol. Survey, Geol. Atlas, Fairfield-Gettysburg folio (No. 225) 1929: Geology of Adams County, Pennsylvania Geol. Survey Rept. C^2, 1927.

Age and correlation. The Gettysburg shale is named from Gettysburg, Adams County, where it was studied in detail and first described. The general soft shaly character of the formation persists where conglomerate or pebbly sandstone do not predominate, but in the Lancaster quadrangle only a small part of the formation consists of soft red shale and sandstone like those in the Gettysburg area. Fossils obtained in York County and elsewhere determine these beds to be of upper Triassic age. The formation is lithologically similar to the Brunswick shale, the upper formation of the Newark group in the eastern part of the State, and they are approximately equivalent.

TERTIARY AND QUATERNARY SYSTEMS.[1]

Terrace Gravel.

High-terrace gravel. A few remnants of river gravel on terraces at an altitude of 520 feet occur on spurs on the south side of Chestnut Hill, northeast of Columbia. The deposit consists of sand, gravel, and rounded cobbles of quartzite which were probably deposited by Susquehanna River when its floor stood at this level. The river has since cut its channel about 300 feet lower, and four small remnants are all that remain of the flood-plain deposit of that stage. It is correlated with the Bryn Mawr gravel, of probable Pliocene age.[2]

High gravel occurs on the hilltops south of Mountville at a somewhat lower level, 440 to 460 feet. Rounded quartzite cobbles and pebbles, quartz sand, some deep-red soil, and a layer of white clay are exposed. These gravely deposits are probably somewhat younger than those on the 520-foot level and are correlated with the Brandywine gravel, of probably earliest Pleistocene age.

Lower-terrace gravel. River gravel occurs on a lower terrace in and south of Columbia and near Washingtonboro, at an altitude of 320 to 340 feet. The gravel on this terrace is characterized by large very scattered boulders of quartzite, 3 feet and more in diameter. These large masses were probably brought down Susquehanna River on floating ice and indicate a cold climate, probably during the glacial epoch, and the deposits are probably of early Pleistocene age. Leverett has recently correlated these gravels with the Illinoian stage of glaciation. The gravel and sand at this level are also present on the hills south of Washingtonboro, and are widely distributed on the hills northwest of Marietta, in the Middletown quadrangle, where they range generally from 360 to 380 feet in altitude and in some places reach 400 feet.

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[1] Frank Leverett, U. S. Geol. Surv. who has been studying these gravels throughout the Susquehanna Valley, is inclined to place all of these gravels under the 600 foot level in the Pleistocene. (G. H. A.)

[2] Stose, G. W., High gravels of Susquehanna River above Columbia, Pa.: Geol. Soc. Amer. Bull. vol. 39, pp. 1073-1086, 1928.

Younger gravels on a terrace at 260 feet altitude occur south of Washingtonboro and extend into the Lancaster quadrangle, and other gravels occur on a still lower terrace, 40 feet above the river.

Recent stream alluvium. Recent alluvium covers the flood plains of the present streams. The alluvium of pratically all the streams in the area is largely fine silt, sand, and fine gravel, derived from soft rocks. None of the flood plains are wide enough to warrant mapping the alluvium. Susquehanna River is more than a mile wide in the quadrangle, and there is no mappable alluvium along it. The islands are mostly bed rock outcrops with thin sand and mud covering.

IGNEOUS ROCKS.

Pegmatite.

Pegmatite composed of coarsely crystalline glassy quartz and pink orthoclase fills crevices in brecciated Cambrian quartzite near Marietta Junction. It occurs at three places in this area—in the Antietam quartzite at the northwestward-plunging end of the northern part of the Chestnut Hill anticline, east of the Landisville road; in the brecciated Antietam quartzite in the faulted area west of the road; and in dark sandy schist associated with Chickies quartzite in the narrow fault block east of the Landisville road. (See fig. 6.)

The pegmatite is in Lower Cambrian strata and therefore was injected into these rocks at least as late as early Paleozoic time. Its deposition appears, moreover, to have been closely associated with the brecciation of the Cambrian strata when they were folded as it fills crevices between breccia fragments, and therefore it may be of late Paleozoic age.

Triassic diabase.

Large sill. The Triassic rocks are penetrated by diabase which occurs chiefly as a thick intrusive sheet between the sedimentary beds but is in part crosscutting. There are also many diabase dikes. The sill extends across the northwestern part of the quadrangle from Hammer Creek to the western edge. It is cut off on the south by a fault running N. 70° E. and is offset by a cross fault that passes between Spring Hill and Governor Dick Hill. In the Hammer Creek valley the sill appears to be cut by the fault.

This large diabase mass is part of the sill that extends southwestward past Lawn to the vicinity of Elizabethtown, in the Middletown quadrangle, and may be called the Lawn sill. In the vicinity of Lawn, where both the top and bottom of the sill are seen to dip 30° NW., parallel to the inclosing strata, it is 1,600 feet thick. This sill apparently lies in the form of a basin, its crosscutting northwestern edge emerging at the surface at the Cornwall mine. Between Governor Dick Hill and Spring Hill the sill is raised so that is is exposed entirely across the basin, but it may be here in part a crosscutting mass.

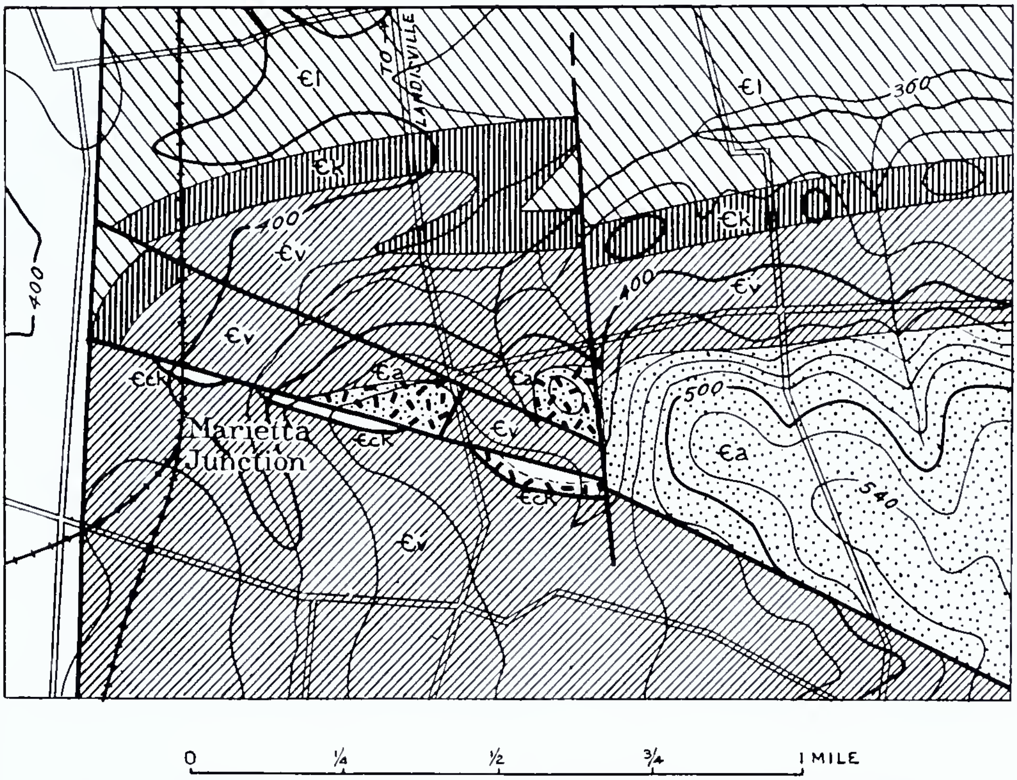


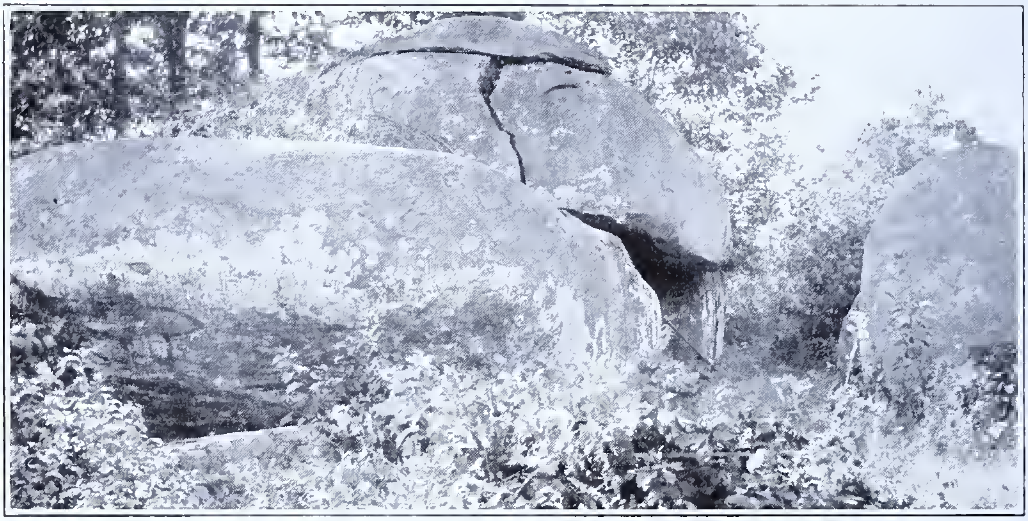
Fig. 6. Geologic map of area near Marietta Junction showing occurrence of pegmatite

Letter symbols are the same as those on geologic map. Pegmatite shown by heavy dashes.

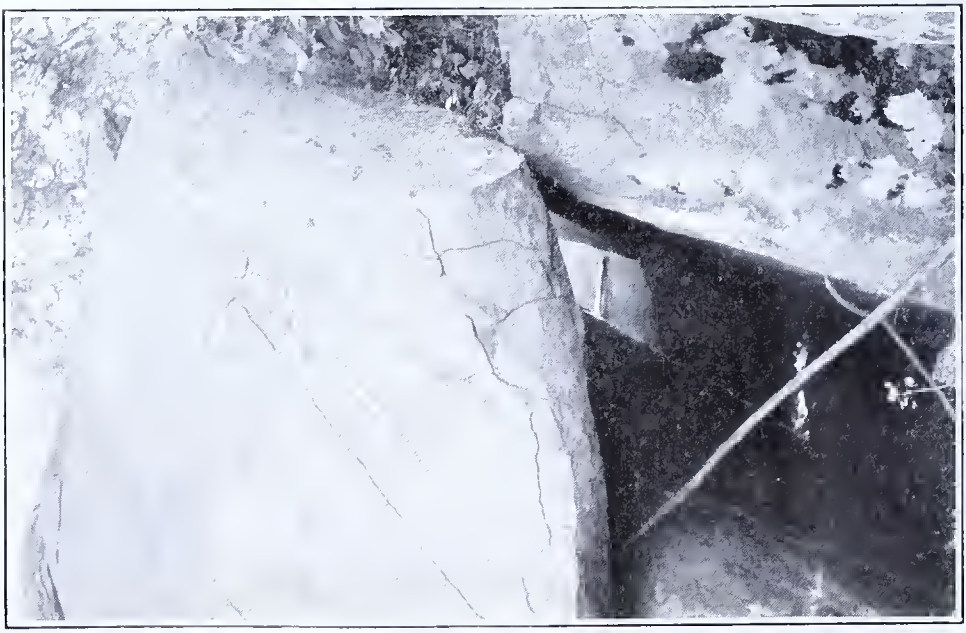
The diabase in the sill is medium to coarse grained, with fine-grained border. The dikes are all fine grained. The diabase is a black to gray crystalline rock with a diabasic or ophitic texture. Its constitutents are grayish feldspar, which is a labradorite, and sparkling green augite. In the coarser grained variety feldspar predominates, and such rock is locally called a grainte. The other minerals present, which can be detected only with the microscope, are magnetite, apatite, and a little quartz. In a part of the area augite is developed in larger crystals, which form bronze spots in the lighter groundmass.

Diabase makes excellent road material because of its hardness and binding qualities, but no quarries in it are being operated in this

PLATE XII



A. Rounded residual diabase masses 1 mile northwest of Mount Hope.



B. Rounded diabase masses displaced to form large caverns. 1 mile northwest of Mount Hope.

quadrangle. Because of their resistance to weathering the larger diabase masses give rise to hilly country with thin soil and for the most part thickly strewn with large rounded diabase boulders (see Pl. XII) whose presence unfits the land for cultivation, consequently these areas are usually left in forest.

The diabase sill has baked the Triassic sedimentary rocks along its borders for a width of about one-eighth of a mile. The baking has indurated the shale into hard resistant porcellanite, has changed its color from red to blue-black by oxidation of the iron content, and has developed new minerals in it. These minerals are epidote and nodules of chlorite pseudomorphic after cordierite. On weathering these nodules stand out like round knots and give the rock a spotted effect. The sandstone is indurated to a hard light-colored quartzose rock, some of which is porous.

Dikes. The dikes are fillings of fissures in the sedimentary rocks by the diabase magma which was intruded between the beds of Triassic sediments to the north and there formed the Lawn sill of diabase. The dikes cut the Triassic rocks as well as the Paleozoic and are therefore of late Triassic age. The longest diabase dike extends south of Naumanville to Salunga, south of which it follows a fault plane in the limestone to Marietta Junction, where it turns at a sharp angle to the southeast along another fault plane and extends south-southeastward to the south edge of the quadrangle.

The next longest dike is in the Cocalico shale and has been traced westward from a point 1 mile west of Whiteoak to the edge of the quadrangle. It is joined by a branch dike 1 mile southeast of Mastersonville and is paralleled by another dike east of Elstonville. There is a dike near Brickerville which extends southwestward to Brubaker and another parallel one to the east. Another dike in the gorge of Hammer Creek apparently cuts Elizabeth Furnace Hill.

GEOLOGIC STRUCTURE.

Sediments are deposited in a flat or nearly flat position, one layer on top of another. In areas that have not been subjected to differential uplift or compression the sediments remain in this horizontal position today no matter how long ago they were deposited. In areas that have been compressed by mountain-making forces within the earth the sedimentary layers become folded. Most of the rocks in the Lancaster quadrangle are greatly folded and do not occupy the positions in which they were laid down. Even the Triassic rocks, the youngest consolidated rocks in the area, have been tilted and broken by faults, but they have not been folded. The older rocks have been flexed into folds that are elongated in a northeasterly direction, normal to the direction of compression. The upfolds are called anticlines and the downfolds synclines. The anticlines and synclines alternate like waves of the sea, the east limb of an anticline forming the west limb of the adjacent syncline. The dip or inclination of the strata varies according to the position of the beds in the fold and the steepness of the folding. The folding in the southern part of the Lancaster area is close and unsymmetrical, the beds on the north sides of anticlines being nearly vertical or even overturned, so that they dip toward the south. The folding is more gentle north of Chestnut Hill and the Fruitville Hills.

During compression within the earth the rocks broke as well as bent, and the breaks thus formed are called joints and faults. Breaks along which there has been little or no movement are called joint planes, and breaks along which there has been displacement of the rocks are called faults. All the rocks of the Lancaster quadrangle have been faulted, and those of the southern part of the area have been much displaced by both normal faults and reverse or overthrust faults. A normal fault is one in which a block of the earth has moved up or down on a vertical or nearly vertical plane with reference to an adjacent block. On some faults there is considerable lateral horizontal movement, and this may predominate over the vertical movement. A dropped block that is bounded on both sides by nearly parallel normal faults is called a graben. A fault block that has been raised between nearly parallel faults is called a horst. A reverse or overthrust fault is one in which one block moves on an inclined plane upward with respect to the adjacent block. Normal or gravity faults are the result of tension in the rocks, whereas thrust faults are the result of compression and usually originate from overturned folds that break along the compressed limb and one part moves up over another part on an inclined plane. Certain great overthrust faults, also called low-angle thrusts, are those along which a large segment of the earth's crust has moved forward and upward over another large segment, usually with a displacement of many miles.

FOLDS

The folding in the Lancaster area is restricted to the Paleozoic rocks, and the trend of the folds is in general N. 80° E. The major uplift is the Chickies-Chestnut Hill anticline, and minor uplifts are the Manor Hills and Mountville Hill anticlines. The chief synclines are the Lancaster-Millersville and Naumanville synclinoriums. (Fig. 7.)

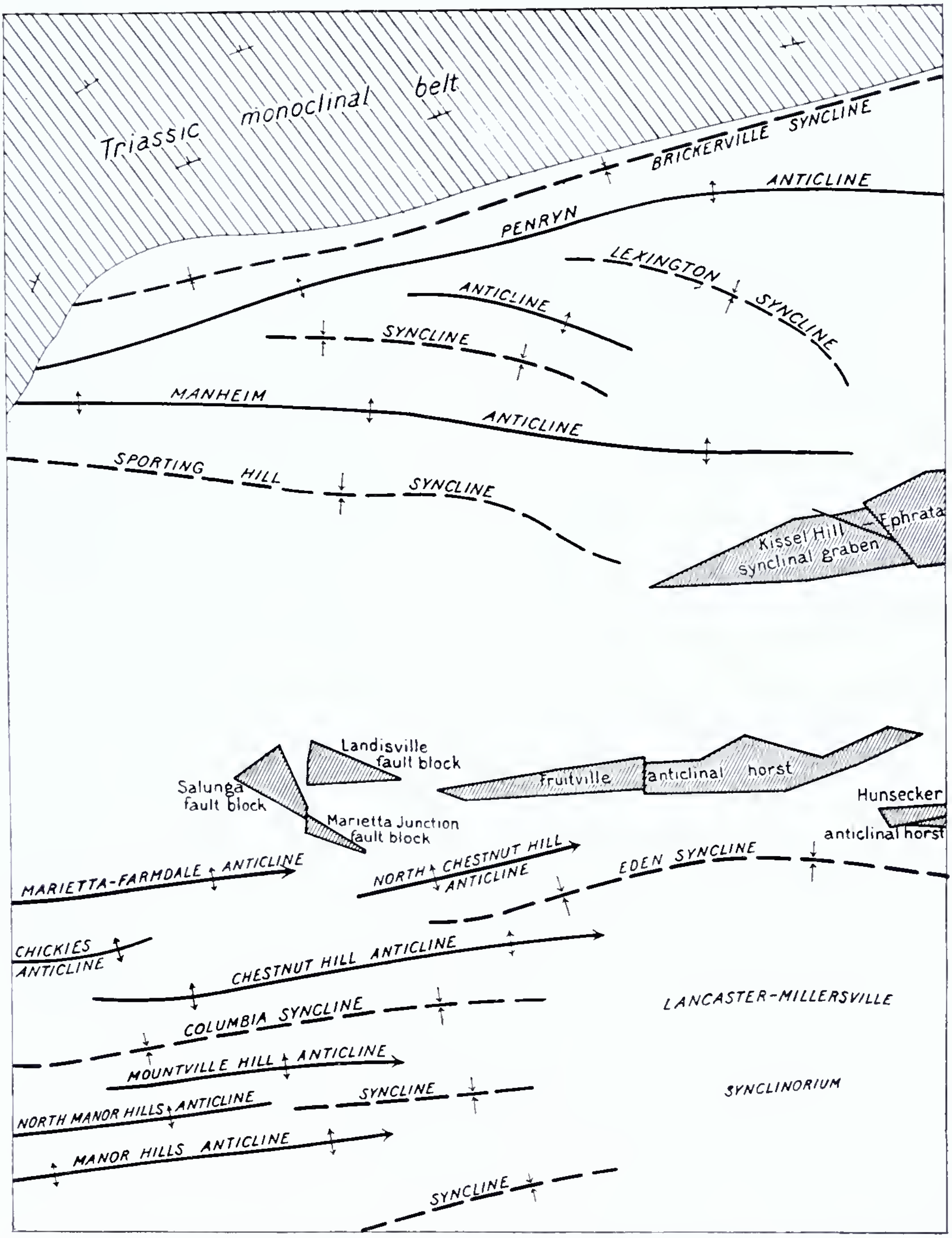


Fig. 7. Structural axes and fault blocks in the Lancaster quadrangle.

Chickies-Chestnut Hill anticline.

The Chickies anticline was named from the exposure of Chickies quartzite in an anticline at Chickies Rock, on Susquehanna River, 1½ miles west of the edge of this quadrangle. (See Pl. V.) This anticline trends east to Silver Spring, and the uplift is continued in the Chestnut Hill anticline nearly to Rohrerstown. The oldest rock exposed in this fold in the Lancaster quadrangle is the Chickies quartzite, which because of its hardness forms Chickies and Chestnut Hills. West of the Susquehanna, in the Hellam Hills, the uplift is greater and the Hellam conglomerate, the basal member of the Chickies, and underlying pre-Cambrian rocks are exposed in this anticline. In Chestnut Hill the fold is essentially simple, except at its west end, but in Chickies Hill it is made up of many minor folds (see Pl. V) which seem to trend diagonally to the general direction of the axis and give a complicated pattern to the area of Chickies quartzite exposed in these folds. The Harpers phyllite and Antietam quartzite overlie the Chickies quartzite on the flanks of the anticline and dip under the Cambrian and Ordovician limestones of the valley, which surround the harder rocks of the ridge on the east and south. The minor folding and faulting at the eastward-plunging end of the anticline is brought out by the sinuous and disjointed character of the low ridges of Kinzers shale in the dolomite lowland. The extreme east end of the plunging anticline is exposed as a low arch of Kinzers formation on the Harrisburg highway 1 mile north of Rohrerstown. (See Pl. XI, B.)

North of Centerville there is a dome-shaped uplift of Antietam quartzite which makes the northeast end of Chestnut Hill. The quartzite dips northward under the Vintage dolomite at Bamford and eastward under the dolomite at Millers Run. A syncline between this uplift and the Chestnut Hill anticline also incloses Vintage dolomite near Centerville. It is possible that this syncline formerly connected with the area of Vintage dolomite south of Silver Spring and that the Chickies-Chestnut Hill anticline, which has been broken by a thrust fault along its north side, was thrust over the dolomite in the syncline. Later extensive block faulting has complicated the structure, and in the eastern part of the fold the structure is so confused that it can not be positively determined.

The Chickies-Chestnut Hill anticline is in strike with the southern part of the Welsh Mountain uplift, 25 miles to the east, and the Fruitville, Hunsecker, and other minor anticlinal uplifts form a broken chain which in a general way connect these major anticlines. The Fruitville anticline is broken by normal faults on its north and south sides whereby it was further uplifted, and it is described below as the Fruitville anticlinal horst.

Manor Hills Anticline.

The Manor Hills anticline, north of Washingtonboro, exposes the Chickies formation at its axis. It is a short anticline cut through by Susquehanna River, and where it plunges eastward the Antietam quartzite and Vintage dolomite dip under the Conestoga limestone of the lowland. A fault along the north side cuts off its north limb. Another anticline of this uplift exposes the Antietam quartzite which forms the northern Manor Hills. It also is cut through by Susquehanna River and is somewhat unsymmetrical, the beds on the south limb dipping 45°-55° S. and those on its north limb being vertical to 70° S. (overturned). The anticline plunges eastward, the Antietam quartzite passing under the dolomite and limestone of the valley.

Mountville Hill Anticline.

A separate and nearly symmetrical anticline of Antietam quartzite entirely surrounded by Vintage dolomite forms Mountville Hill. The dips on both limbs are about 55° away from the axis. The fold plunges abruptly eastward but not so abruptly toward the west, where the sandy and slaty beds at the base of the Conestoga limestone exposed in a plunging anticline crop out more than a mile west of the Antietam quartzite.

Marietta-Farmdale Anticline.

An anticline in the limestone north of Chestnut Hill brings up the Ledger dolomite at Farmdale. Farther west this anticline rises to greater prominence, and the Antietam quartzite makes conspicuous exposures from Marietta westward to the Susquehanna. This anticline lies north of the Chickies overthrust fault.

Lancaster-Millersville Synclinorium.

A broad compound syncline lies south of the Chestnut Hill anticline and Fruitville anticlinal horst and extends across the southern part of the quadrangle. It is underlain by the Conestoga limestone, which is closely folded and crumpled. The syncline fingers out westward between anticlinal uplifts, the northern branch passing north of the Mountville Hill anticline and extending to Columbia; another branch lying between the Mountville Hill and Manor Hills anticlines; and the largest branch lying south of the Manor Hills. The south limb of this synclinorium is formed by anticlinal hills of Antietam quartzite in the McCalls Ferry quadrangle.

Eden Syncline.

There is a minor syncline inclosing Conococheague limestone at Eden, north of Lancaster. It separates the two eastern prongs of the Chestnut Hill anticline east of Centerville, whence it plunges eastward toward Roseville. It is the west end of a syncline which lies between the two westward-plunging anticlinal prongs of the Welsh Mountain uplift, in the New Holland quadrangle.

Naumanville Synclinorium.

The Cocalico shale around Naumanville occupies a broad syncline which toward the east is divided into three synclines separated by two anticlines. The southern syncline extends through Sporting Hill and Kissel Hill. It is the westward extension of the Ephrata syncline of the New Holland quadrangle, where the syncline contains not only Cocalico shale but remnants of overlying Triassic sandstone. The Manheim anticline, exposing the Beekmantown and Conococheague limestones, separates this southern fold from a middle syncline of shale which trends southeastward through Lexington to Brunnerville. The anticline is probably indicated in the shale west of Naumanville by the bands of purple and green shale and hard sandstone which occur near the base of the Cocalico formation. The middle syncline is separated from the northern syncline of shale at Brickerville by the Penryn anticline which brings Beekmantown limestone to the surface south of Clay. The bands of purple and green shales and thin quartzite at Penryn, Whiteoak, and Union Square, represent basal beds of the Cocalico brought up by this anticline within the shale area.

FAULTS.

Thrust Faults.

There is only one fault in the area that is quite certainly a thrust fault. The anticline that forms Chickies and Chestnut hills has been broken on the north side, and the Cambrian quartzose rocks in the anticline have been thrust northward over younger limestones of the valley. This fault has been traced from the mouth of Codorus Creek, in the Middletown quadrangle, eastward to Centerville. East of the mouth of Codorus Creek the trace of the fault plane lies along the north side of the Hellam Hills as far as Hellam Point. Here the fault crosses Susquehanna River to the north side of the Chickies anticline. At Accomac, a mile west of Hellam Point, pre-Cambrian and basal Cambrian rocks are exposed in the highest point of the anticline thrust over Ledger dolomite. In the Lancaster area as far east as Silver Spring the Chickies quartzite and Harpers phyllite are thrust over the Conococheague limestone along the fault plane.

The overthrust block is offset one mile by a later diagonal normal fault which passes northeastward through Columbia, and the north edge of the overthrust block is offset to Ironville, whence it extends eastward again. In this part of the fault the Chickies quartzite and Harpers phyllite are overthrust onto the Vintage dolomite of the lowland south of Silver Spring. The structure of the eastern part of Chestnut Hill is greatly confused by a network of normal faults, and the thrust fault is lost in the maze and can not be distinguished farther east.

This thrust fault appears to be the northern broken edge of the main anticline of the Chestnut Hill uplift overthrust northward onto the Vintage dolomite in the medial syncline of the uplift. If this is so, the throw of the fault would diminish eastward as the folds plunge in that direction and would die out in the limestone not far east of Centerville. The confusion due to numerous normal faults in this locality makes the structure uncertain. It is possible that the thrust may involve a much greater overthrust block that includes all of Chestnut Hill and the intricate chain of fault blocks extending from Salunga through Landisville, Fruitville, and Landis Valley and north of Binkley. In that event the thrust fault is buried in the blocks that have been dropped by normal faults.

Normal Faults.

The rocks of the Lancaster quadrangle are much broken by normal faults. These faults are especially numerous in the south-central part of the area, where they are so intricate that they make the solution of the geology a difficult problem. They follow four general directions—N. 60° E., N. 60° W., east, and north. The east and the N. 60° E. faults are in general older than the N. 60° W. faults, which cut them. The northerly system is apparently the most recent of the series, for the faults of this system offset all the others. This is very strikingly shown by the north-south fault through Fruitville, which offsets the easterly faults that bound the Fruitville horst.

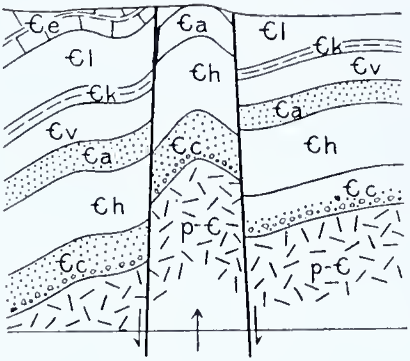
The movement along some of these normal faults appears to be largely horizontal. The offsetting of the Fruitville horst, whose sides are probably nearly vertical, amounts to a quarter of a mile and could be accomplished only by horizontal movement. Similar offsets of formations and normal fault blocks may be observed along the north-south fault west of Marietta Junction, the movement of which was probably also largely horizontal. The greatest areal displacement of formations is along the diagonal faults northwest and southeast of Columbia. The formations here are inclined, and their offset 1 mile by these faults is probably due largely to vertical movement. The horizontal movement seems to be restricted to the system of north-south faults, which was also the latest.

Normal faults not only produce offsets in the strata, but where they are parallel to the strike they cause beds to disappear and to be repeated. The broken up triangular area south of Salunga is a conspicuous example of repetition of beds by faulting. The normal strike fault at Penryn Station cuts off the conglomerate member of the Gettysburg shale north of Mount Hope. The relative movement has been down on the south side of the fault, tilting the blocks northward, as is usual in this region. The movement on the east-west fault north of Lititz, on the other hand, is upward on the south side, the fault bringing the Conococheague limestone into contact with Cocalico shale north of the fault.

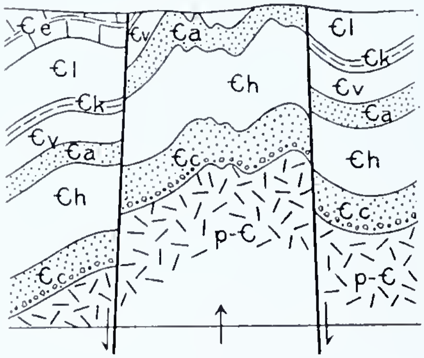
Fruitville Anticlinal Horst.

A narrow belt of rocks older than the adjacent formations and bounded on the north and south by nearly parallel normal faults extends more than halfway across the quadrangle from the vicinity of Oregon to Landisville. The Antietam quartzite forms the Fruitville Hills, in the center of the uplift, and several smaller hills at the axes of lesser uplift. This block has risen in reference to the rocks north and south of it and thus forms a horst. (See fig 8.) Similar structural features having an anticlinal structure occur to the east and have been described by Stose[1] as anticlinal horsts.

The Fruitville horst has been broken into several blocks by later



Section E-E'



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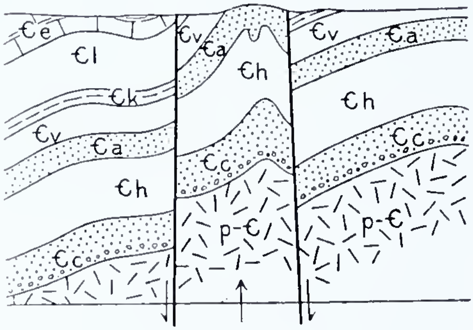
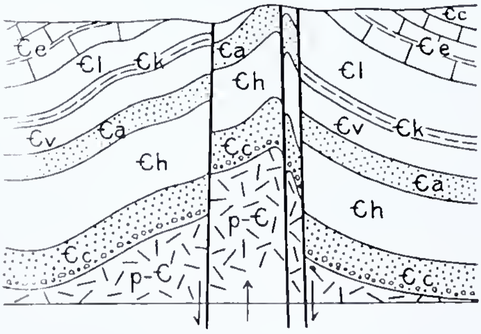


Section G-G'



Section H-H'

ONE MILE.

Fig. 8. Sections across the Fruitville anticlinal horst.
Letter symbols are the same as those on the geologic map, Plate II.

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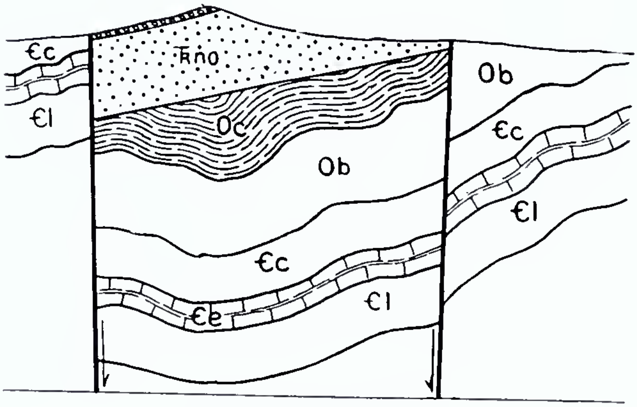
[1] Stose, G. W., Geol. Soc. America Bull., vol., 35, pp. 465-480, 1924.

transverse faults. A north-south fault through Fruitville divides it into an eastern and a western part, and a diagonal fault cuts off another smaller block south of Landisville. On the west the horst is terminated by a north-south fault through Marietta Junction.

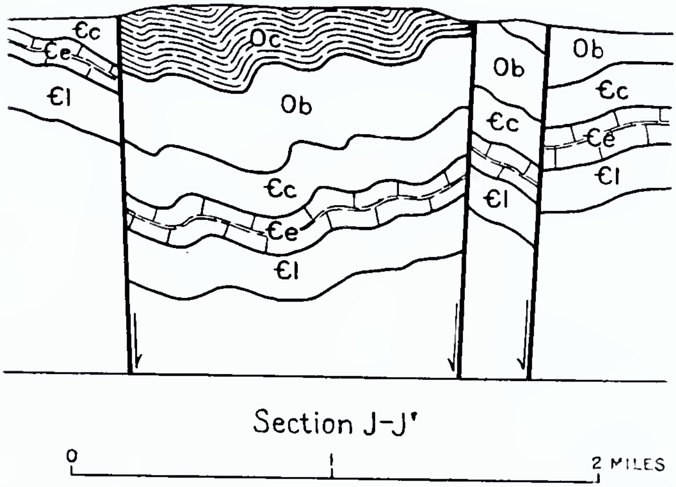
The west end of a similar block, called the Hunsecker anticlinal horst, occurs north of Binkley. It is part of the Laurel Hill anticlinal horst of the New Holland quadrangle and is bounded on its north and south sides by nearly parallel normal faults. The Antietam quartzite is exposed in the center of the uplift and forms the hill north of Binkley.

Kissel Hill-Ephrata Synclinal Graben.

The structural opposite of the Fruitville anticlinal horst is the synclinal graben extending eastward from Kissel Hill to Ephrata. (See Fig. 9.) It is a syncline inclosing Cocalico shale which



EAST OF EPHRATA



Section J-J'

Fig. 9. **Sections across the Kissel Hill-Ephrata synclinal graben.**

Letter symbols are the same as those on geologic map.

has been dropped along nearly parallel bounding faults on the north and south sides. The faulting was accompanied by a northward tilting of the blocks, the downward movement on the northern fault being the greater. In the vicinity of Ephrata the synclinal graben deepens and the Triassic rocks which are preserved on top of the Cocalico shale are tilted northward.

Age of the Structural Features.

The folds in the Paleozoic rocks of the quadrangle are older than the normal faults that cut them and also older than the Triassic sediments that lack this folding. The trend of the folds is parallel to that of the general Appalachian folding. Although in the area adjoining the Lancaster quadrangle minor folding took place during early Paleozoic time, most of the folding occurred after all the Paleozoic sediments now present were deposited. The general folding in the Appalachian region occurred chiefly at the end of the Paleozoic era, during a period of great compression and mountain building when all the rocks in the Appalachian geosyncline were folded. The folding in the Paleozoic rocks of the Lancaster quadrangle and the associated overthrust faulting on the north side of the Chickies-Chestnut Hill anticline probably took place therefore at the end of Paleozoic time.

The Triassic rocks in the northern part of the Lancaster quadrangle are broken by normal faults of late Triassic age, but none of these faults have been clearly traced into the older rocks. Most of the faults in the Paleozoic rocks of the quadrangle are normal faults of Triassic type and are also considered to be of late Triassic age, because Triassic rocks are involved in the normal faulting in the eastern part of the Ephrata syncline, just east of the Lancaster area, and elsewhere in this region. The fault movement was generally accomplished by shattering of the rocks in the fault zone, and the breaks were later sealed with quartz, which is commonly found in the soil along these fault zones.

MINERAL RESOURCES.

Introduction.

The mineral resources of the Lancaster quadrangle, in order of economic importance, comprise limestone, clay, sand, building stone, iron, lead, and zinc. Limestone occupies a large part of the area and has been extensively quarried for many years. Clay is dug for making brick, for which there is a large demand. Sand is dug for local use in building. Formerly the Lancaster region produced large quantities of iron ore, which was smelted in local blast furnaces.

LIMESTONE.

Limestone is a sedimentary rock formed by chemical precipitation from solution or by the accumulation of fragments or whole shells of organisms that secrete calcareous tests. Pure limestone is calcium carbonate, but few limestones are pure, and most limestones contain variable amounts of magnesia, silica, iron, and alumina. Rock containing over 21 per cent of magnesium carbonate is called dolomite. Limestones vary in color, thickness of beds, and character of weathering, as well as in composition, and they vary in appearance according to whether the rock is amorphous or distinctly crystalline. In general increased crystallinity is marked by a lightening of color. Thus, marble is usually light blue or light gray to white.

The chief difference in physical appearance is due to a difference in chemical composition. Pure limestones are usually cream-colored to dove-gray or blue; argillaceous or carbonaceous limestones are dark blue or black. Magnesian and siliceous limestones are harder and heavier than pure limestone or the argillaceous varieties and weather to a rough surface. The limestones of the Lancaster area can be largely divided into two classes—dense, thick-bedded crystalline limestones and dolomite, and thin-bedded limestones with slaty partings.

The oldest limestones (Vintage and Ledger) are dense dolomites; the younger limestones (Elbrook, Conococheague, and Beekmantown) are mostly dense limestones, magnesian only in part. The Conestoga limestone, the youngest in the area, is thin-bedded and slaty. The active quarries of the Lancaster quadrangle are largely in the Conococheague, Beekmantown, and Conestoga limestones.

Uses.

Limestone is used extensively for so many purposes that a complete discussion can not be given here. Only some of the principal uses can be mentioned. Its largest use is to supply crushed stone for road material, ballast, and concrete. It is widely used as fertilizer in the form of finely ground limestone and of burned lime; as building stone, including curbing and flagging; and as fluxing stone in the smelting of iron ore. It has a continually increasing use in the manufacture of Portland cement. It is burned to lime and to hydrated lime for mortar and plaster. Dolomite furnishes a refractory furnace lining and is also used in the manufacture of magnesium products. The chemical uses of lime are many, chief of which are in glass manufacture, in bleaching and tanning industries, and in the manufacture of paint, varnish, paper, soap, sugar, and various chemicals. For the most part a high-calcium lime is desirable for chemical use.

Limestone production in Pennsylvania increased greatly in 1926,[1] when 13,250,290 short tons was quarried, with a value of $13,447,371.

This value was surpassed by only one other State, Indiana, which led because of the greater value of its limestone building stone. In 1927 the production fell off about 870,000 tons, but in 1928, because of improved business conditions, there was an increase of 9 per cent for the country as a whole, and part of this increase is represented by Pennsylvania's production.

Crushed Stone.

In the Lancaster quadrangle the chief use of limestone is to supply crushed stone for road metal. It is used also for making concrete and for ballast for electric railroads.

In the early days limestone was quarried for building stone because of its availability, and the older houses and barns built of limestone add greatly to the beauty of the countryside. Concrete blocks made of finely crushed limestone and cement and poured concrete foundations have largely superseded limestone as building stone because of their greater cheapness, although buildings constructed of them are less pleasing in appearance. There are several plants engaged in the manufacture of concrete building blocks in the vicinity of Lancaster; the largest is the plant of the Kurtz Bros. Concrete Product Co. near Ephrata.[2]

Except for the Harrisburg road and the Ephrata-Lebanon road, which are made of Portland cement concrete, the highways in the Lancaster quadrangle are macadam with a bituminous binder, or bituminous macadam with a seal coat. The bituminous macadam is laid on a prepared base, usually coarse broken stone. Concrete foundations for roads are not used in this area.

In determining the limiting value for crushed stone in various types of road construction tests are made to determine the specific gravity, percentage of wear, toughness, and crushing strength. The following table is based on data supplied by the Pennsylvania Department of Highways. The locations of the quarries from which the stone tested was obtained are shown on the map.

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[1] Coons, A. T., U. S. Bur. Mines Mineral Resources, 1926, pt. 2, p. 227, 1927.

[2] Jonas, A. I., and Stose, G. W., Atlas of Pennsylvania, New Holland quadrangle; Pennsylvania Top. and Geol. Survey, No. 178, p. 27, 1926.

Results of tests of crushed stone from the Lancaster quadrangle.
(Made by the Pennsylvania Department of Highways)

No. on map	Owner or operator	Type	Specific gravity	Weight (lbs.) per cubic foot	Absorption pounds per cubic ft.	Coefficient of wear	Toughness (a)	Crushing strength by pounds per sq. inch (b)
4	Theodore L. Forney	Limestone	2.72	169.7	0.25	4.9	9	--------
6	Elmer H. Hershey	do	2.75	171.7	.31	4.5	9	--------
7	J. B. Bucher	do	2.73	170.4	.36	5.0	25	23,515
8	C. B. Winters	do	2.77	172.9	.61	5.1	15	24,080
14	Binkley & Ober	do	2.71	169.1	.66	3.1	--------	21,327
15	J. N. Stauffer & Bro.	do	2.68	167.2	.17	2.8	--------	46,707
17	A. M. Eshleman	do	2.83	176.6	.62	3.7	12	15,420
19	J. C. Budding Co.	do	2.85	177.8	.35	2.8	--------	36,191
25	J. M. Brunner	Dolomite	2.71	169.1	.54	5.5	12	--------
27	Brookmeyer & Goshkey	Limestone	2.72	169.7	.27	3.5	10	18.729
28	H. Ray Miller	do	2.73	170.5	.44	3.0	6	15.749
29	C. D. Stoner	do	2.75	171.7	.36	5.9	--------	--------
30	C. D. Stoner	do	2.73	170.4	.34	3.2	--------	15.210
31	Charles S. Bender	do	2.76	172.3	.76	4.5	11	--------

(a) Represents number of blows and drops of hammer in centimeters in Page impact machine to produce failure.
(b) In cylinder 1 inch in diameter and 1½ inches high.

All the rocks tested show a toughness of over 5 with a maximum of 25. The coefficient of wear is, however, rather low, for the most part under 5. The rocks are all rated as limestones except that from the J. M. Brenner quarry, which is dolomite. All of them show crushing strength in excess of the State Highway Department requirements. The absorption, or the ability to absorb moisture, is low, averaging less than 0.50 pounds per cubic foot. This low absorption, which is due to the denseness and crystallinity of the rocks, increases their durabilty when exposed to frost action.

Burned Lime.

The production of burned lime in the Lancaster quadrangle is subordinate to that of crushed stone. Lime is burned to some extent at four quarries near Lititz and Manheim, which are described under the heading "Active quarries." The quarries supply a local use. Twenty years or more ago farmers burned lime in their own kilns, and many of the better-built kilns still stand like masonry towers near the old quarries. The cheapness and convenience of prepared bagged lime and the high cost of fuel and labor at the kilns have caused the abandonment of most of the local lime burning. Lime is burned on a large scale at several plants in the vicinity of York, 25 to 30 miles west of Lancaster.

Cement.

The Lancaster area has been prospected for limestone suitable for cement, but no plants have yet been located in this quadrangle.

The limestone that is nearest in composition to a natural cement rock is the Conestoga limestone, but it is so variable in physical and chemical composition and contains so much pyrite that it is of doubtful value for this purpose. Certain beds in the Beekmantown limestone are pure enough to produce a good Portland cement rock by mixing with shale.

It is obvious that a limestone to be of value for Portland cement must have potential advantages of location and physical character besides proper chemical composition, important as that is. The Lancaster area is well located with respect to market, fuel, and transportation routes, being crossed by the main line of the Pennsylvania Railroad from Philadelphia to Pittsburgh and the West. The feasibility of establishing a cement plant in this area depends largely on the demand for the product and the finding of a location where a large supply of raw material is available. A cement plant uses each year a large quantity of limestone and shale, and anyone intending to construct such a plant in this area should be assured of the quality and quantity of limestone available by thorough drilling and analyses of samples.

Active Quarries.

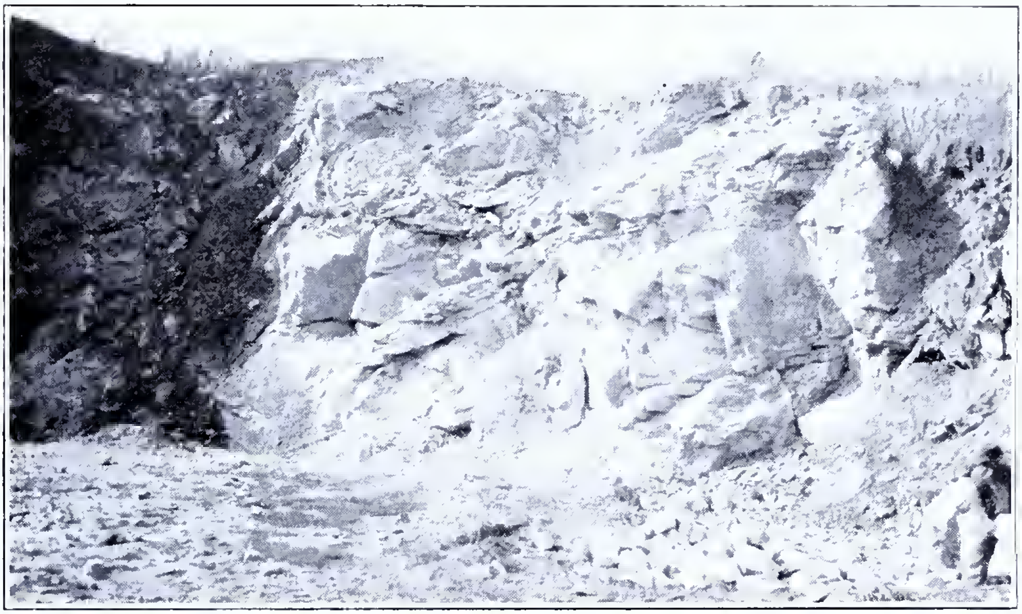
There are many limestone quarries, active and inactive, in the Lancaster quadrangle, and their distribution is shown on the topographic map that accompanies this volume. The older quarries, now abandoned or only occasionally worked, are indicated on the map by a prospect symbol. They were used for obtaining building stone, crushed stone, and rock for burning to lime. The active quarries are indicated on the map by crossed hammers and numbers, and their products and the formation in which they occur are described below in the order of their numbers.

Quarry 1 is 1 mile west of Clay, in the valley of Beekmantown limestone bordered by Cocalico shale. It is worked by Isaac Stauffer. The rock is dense blue limestone, which dips 55° NE. and furnishes good crushed stone for road material.

Two other quarries are operated in the same valley. C. P. Risser's quarry (No. 2) lies a mile south of the Isaac Stauffer quarry and north of Hammer Creek. It is operated by Anderson Shoemaker of Lititz, and is equipped with a small jaw crusher, screens and bins, and scale. The crushed stone is marketed by wagon. A mile to the south of this quarry is that of John Seibert (No. 3), which is worked occasionally for crushed stone.

Theodore Forney, of Lititz, operates a quarry (No. 4) just north of Lititz. The rock is Conococheague limestone, a dark-blue hard limestone with a dip of 15° E. (Pl. XIII, A.) The quarry is at present opened along the strike with a 75-foot face and has 4 or 5 feet of clay overburden and 10 feet of rotten rock which must be stripped off.

PLATE XIII



A. West end of Forney quarry, north of Lititz, showing at left overturned recumbent fold in Conococheague limestone.

B. Quarry of Ramoth Lime & Stone Co. in Conococheague limestone at Limerock, 2 miles west of Lititz.

The quarry measures 200 feet east and west by 50 feet north and south. The rock is blasted and then broken out by hand. A Marion steam shovel, type 21, is used to load the tram cars, which are hauled by cable to the crushers. Two types of crushers are used—a Champion No. 5 and a New Holland. The crushers, water pump, compressor, and other equipment are operated by four electric motors. There is also a blacksmith shop, two pan-elevators, and elevated bins for small and large sizes with a loading tunnel for trucks. The quarry employs 18 men and produces crushed stone for roads and concrete, which is hauled by trucks to State roads and State-aid roads.

A mile to the west Albert Shenk is operating a small quarry (No. 5) in the same formation. The rock is broken out by hand and crushed for road metal. The quarry was opened in 1925.

Elmer Hershey, of Lititz, now operates the ''Rome'' quarry (No. 6) for crushed stone. He purchased it recently of the widow of Aaron Long. It has a 40-foot face of blue sparkling limestone and mottled marble (Conococheague), which is much folded but has a south dip. The quarry is about 60 feet square.

At Limerock, 2 miles west of Lititz, there is a large quarry (No. 7) south of the Philadelphia & Reading Railroad. It was formerly worked by the Ramoth Lime & Stone Co., of Lebanon, but is now run by J. D. Bucher. (See Pl. XIII, B.) The quarry is equipped with two crushers and a pulverizer. It produces crushed stone in five sizes and agricultural ground limestone. Some lime is burned. The equipment was operated by steam until 1925, when an electric motor was installed which uses power furnished by the Edison Electric Co., of Lancaster. The quarry is 200 feet long parallel to the strike, east and west, and about 100 feet across the strike, with a 30-foot operating face. The rock is hard blue to gray limestone which dips 20° S. The blasted rock is loaded into iron tramcars, which are drawn by cable to the crusher. Another quarry, about 100 feet square, now idle, lies to the east of the active quarry.

There are no analyses available for the Beekmantown or Conococheague limestone in the area of quarries 1 to 7. Quarries 8 to 12 are in the Beekmantown limestone in the vicinity of Manheim and Lancaster Junction, north and south of the syncline of Cocalico shale that passes through Sporting Hill. The only analyses of Beekmantown limestone from this belt represent samples from the area south of Sporting Hill and are given in the table on page 80 (Nos. 1 to 12). For the most part the rock is high in calcium and low in magnesium and contains a very noticeable amount of silica.

Just north of the Manheim borough line is the Charles Winters quarry (No. 8), near the contact of limestone and overlying Cocalico shale. It has been operating for four years and in 1925 supplied the crushed stone for the State road built from Manheim northward to the Lebanon County line. The quarry supplies a local trade for crushed stone for roads and concrete. It is equipped with two crushers, which are operated by a steam tractor, with pan-elevators and bins. The blasted rock is broken by hand and hauled in horse-drawn carts and Ford trucks to the crusher. The quarry is 50 feet in diameter with a 30-foot face, and there is only 5 feet of soil overburden.

Half a mile southeast of the Winter quarry is one operated by William Gantz (No. 9). The rock is well-bedded blue argillaceous limestone, which is quarried as needed and burned for field lime. The quarry is a large shallow opening much of which is filled with water, and operations are conducted in a small part of it. There are three stone kilns, and coal is used for fuel.

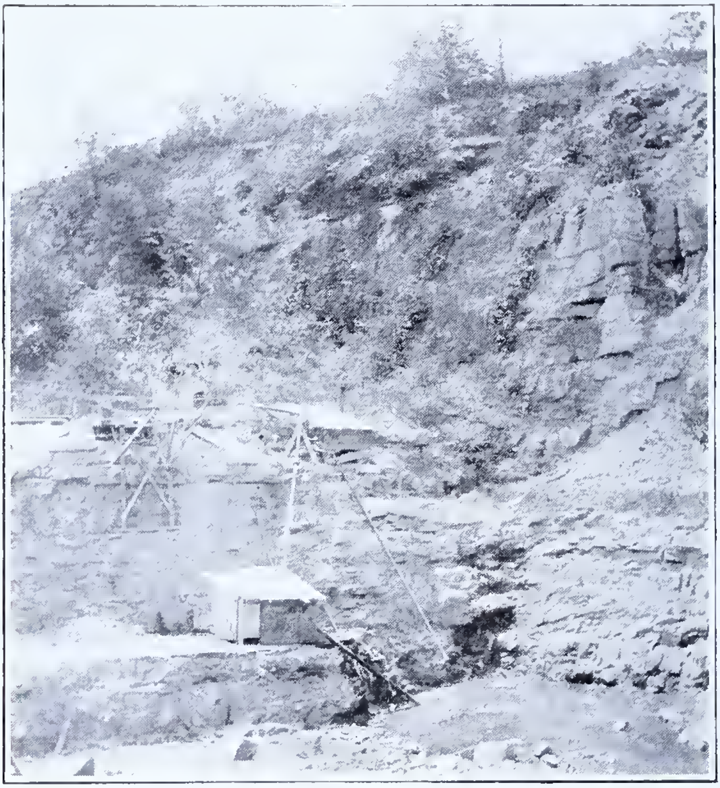
Quarry 10 is south of the road to Sporting Hill, west of Chickies Creek. It is owned by A. F. Metzger, of Manheim. After it had been idle for several months in 1925, a new face was prepared by stripping 10 to 20 feet of shale from the north end of the quarry. The old face was 60 feet above the water surface in a hole filled by water (Pl. XIV, A). The rock is a hard, well-bedded blue limestone and dolomite with argillaceous partings, dipping 15° SW. under the shale. The quarry is equipped with crusher and bins, with tram and cable to carry the rock to the crusher. Electric power is used. The product is crushed stone which is delivered by truck.

The J. L. Kauffman quarry (No. 11) lies half a mile south of the Cocalico shale area at Sporting Hill. The quarry has three stone kilns, but lime has not been burned recently. A considerable area has been stripped, and the quarry face is about 20 feet high, exposing a thickness of 100 feet of beds that dip 80° N. The upper 30 feet consists of blue limestone and light-colored dolomite, containing gastropods of upper Beekmantown age. Below it there is 25 feet of white and dove-colored fine-grained marble overlying 45 feet of limestone in which banding shows on weathering. The fine-grained marble and blue limestone are high in calcium and would produce high-grade lime. This quarry has a crusher, pan-elevator, and bins, and a hydrating plant may be installed.

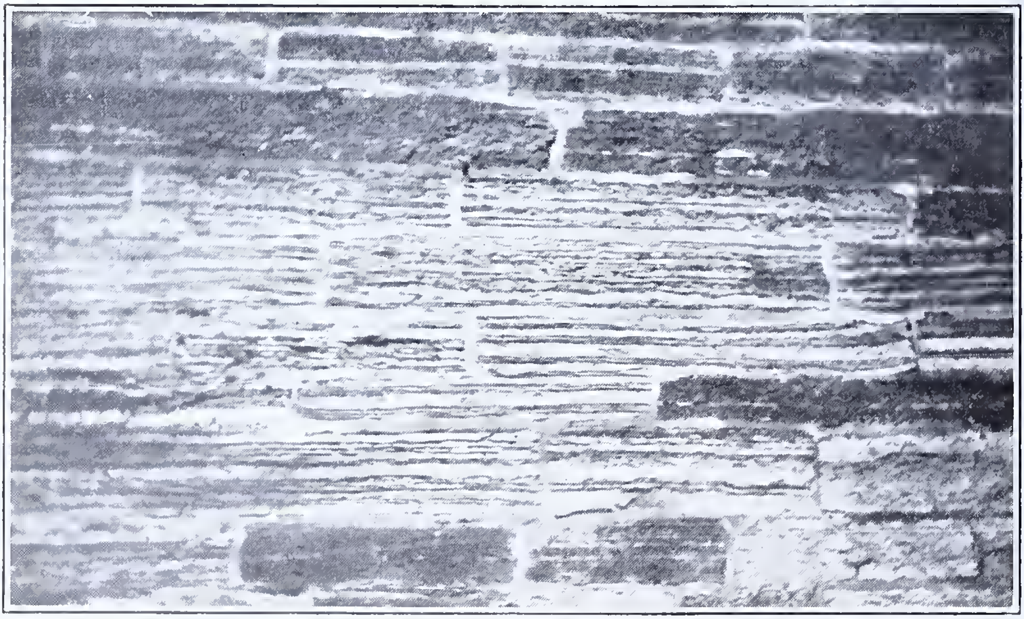
Another quarry in the Beekmantown at which lime is burned is that of Thomas A. Erb (No. 12), R. D., Lititz. The quarry lies 3 miles east of Lancaster Junction. The beds exposed are black crystalline limestone and gray dolomite; the limestone is burned for lime, and the dolomite is used for crushed stone. The quarry is about 150 feet square with a 30-foot face.

In the summer of 1925 Abraham E. Binkley, of Neffsville, opened a quarry (No. 13) on the Buckwalter farm, 1 mile southeast of Kissel

PLATE XIV



A. Metzger quarry, 1 mile southwest of Manheim, showing horizontal beds of limestone and dolomite of the Beekmantown.



B. Banded blue limestone of the Conestoga formation, extensively used as building stone in Lancaster. Retaining wall at old Pennsylvania Railway Station.

Hill. The quarry is in the upper part of the Conococheague limestone and is 15 feet deep and 100 feet across, and faces south. The top rock is even-grained dove-colored to blue limestone dipping 30° N., overlying harder limestone of similar color. This quarry produces crushed stone and is equipped with a portable engine, crusher and screens, and bins.

Another quarry recently brought into operation is that of Binkley & Ober (No. 14), north of East Petersburg. It is in dark-blue dolomite of the Conococheague, which furnishes excellent road material. Power for the crusher is furnished by a steam tractor, and the product is screened into two bins and shipped by truck.

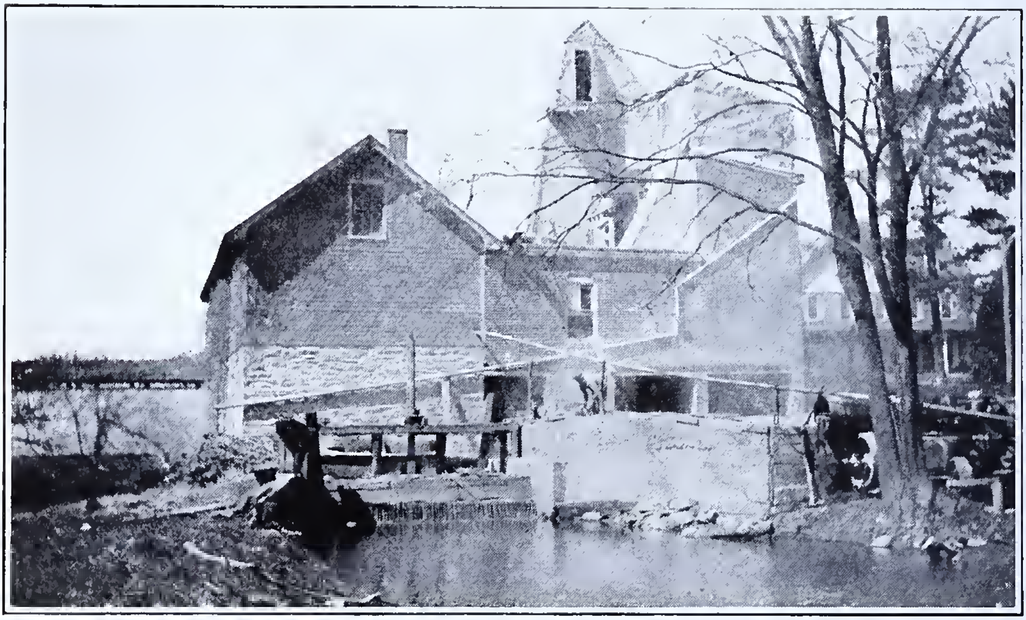
There are many quarries in the Beekmantown limestone near Mount Joy which are no longer operating. One of the active quarries is that of J. N. Stauffer & Bro. (No. 15), R. D. 2, Mount Joy, on Little Chickies Creek 1 mile north of Mount Joy. The quarry is cut into the hill 100 feet and has a 60-foot face, 1,000 feet long, facing south. Horse-drawn carts haul the stone to two crushers which have pan-elevators and two large elevated bins with concrete foundation built over a loading tunnel. A third crusher with pan-elevators and bins is used on emergency when the quarry is working to capacity. An analysis of the Beekmantown limestone is given as No. 13, page 80.

At Centerville, 3 miles southeast of Mount Joy, there are two active quarries (Nos. 16 and 17) in the Conococheague limestone. Analyses 14 to 17 of the rock near these quarries show considerable magnesium carbonate, but the rock of analysis 13 is a high-calcium carbonate. All of them contain rather a high percentage of silica, which unfits the rock for lime burning.

Quarry 16 is operated for crushed stone by N. S. Newcomer, of Mount Joy. The rock is blue wavy-bedded limestone and dolomite, much veined by white calcite. It is quarried north of Chickies Creek and hauled south across the creek one-sixteenth of a mile to the crusher. The crusher and plant are in an old mill (Pl. XV, A) formerly a grist-mill, and utilizes water power from Chickies Creek (Plate XV, B). The plant is equipped also with accessory electric motors, which, however, are rarely needed. It has an elevator and brick bins for the crushed stone, which is shipped by truck for road material and concrete.

The second quarry near Centerville (No. 17) is that of A. M. Eshleman, of Landisville It is half a mile east of the Newcomer quarry, on a tributary of Chickies Creek, and has been in operation since 1922. The rock is blue dolomite and white marble dipping 20° N. It is quarried into the hill for 100 feet along the strike, with a 20-foot face. Because of its proximity to the creek considerable water seeps in and prevents quarrying deeper. There is about 3 feet of soil to be stripped, which will increase in thickness as the workings are extended westward into the hill. The stone is blasted and sledged and

PLATE XV



A. Crushing plant of Newcomer quarry, Centerville, converted water-power gristmill.

B. Dam on Chickies Creek at Centerville, from which power is obtained to run Newcomer plant.

taken by tramcar to the crusher. There are two pan-elevators and elevated bins. The machinery is run by a portable steam tractor, and the crushed stone is delivered by two Mack trucks.

Another small quarry (No. 18) in Conococheague limestone in the same vicinity is operated by I. S. Siegrist, of Columbia. The quarry is south of Farmdale, in dark-blue argillaceous dolomite, and was idle in 1925.

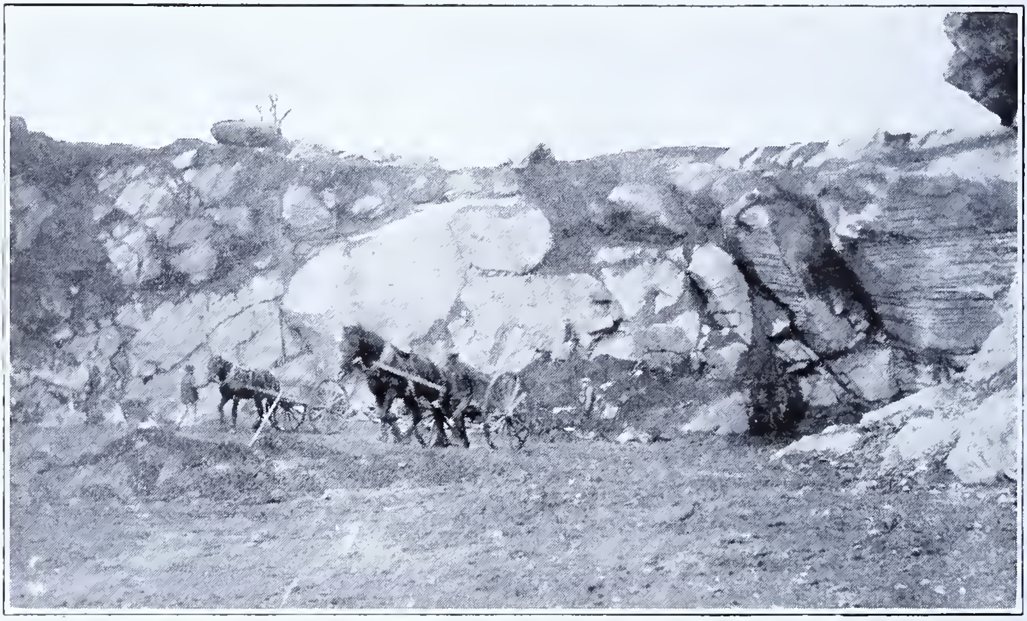
The two quarries Nos. 19 to 20 opened in the Ledger dolomite are idle. The Bellemont quarry (No. 19) 1 mile north of Lancaster, is owned by Aaron B. Hess, of Harrisburg, and was operated by J. C. Budding before 1923 for crushed stone and lime. The quarry is 800 by 400 feet and has a 20-foot face above the water that fills the hole. The rock is a white and blue mottled dolomite and has been analyzed by the Bethlehem Steel Co. (See No. 18 page 80). It is a dolomite with a little silica and closely resembles in composition the Ledger dolomite in the area near Newtown, as is shown in analysis 19.

The quarry of the Dolomite Products Co. (No. 20), near Shreiner station, is in the same formation—typical Ledger dolomite. The company, whose address is Brenneman Building, North Duke Street, Lancaster, formerly operated this quarry for the manufacture of magnesium products and equipped it with large buildings and machinery, which are now abandoned and falling into decay. A spur of the Philadelphia & Reading Railroad runs into the plant.

Another abandoned quarry in the Ledger dolomite is 3 miles west of Shreiner, near the former lead and zinc mines at Bamford. This quarry was operated by the J. E. Baker Co. for high-magnesium fluxing stone, but it has been abandoned in favor of this company's large quarry at Bainbridge, Lancaster County, on Susquehanna River, which produces better fluxing stone at a lower cost.

In the vicinity of Lancaster there are eight active quarries in the Conestoga limestone, as well as many smaller openings which are occasionally worked. Northeast of Lancaster and east of Rossmere, Clarence D. Stoner, of Columbia, operates a quarry (No. 21) for crushed stone. J. C. Budding, of Lancaster, is the agent for handling the stone. The quarry is 200 feet long and has a 20-foot face of thick-bedded ribbed limestone overlain by 5 to 10 feet of argillaceous softer rock. It is cut northwest into the hill, diagonal to gently dipping beds in an anticline. (See Pl. XVI, A.) Horse-drawn carts take the stone from the quarry to the crushers, which are of the Champion type, three No. 4 and one No. 6. All sizes of crushed stone are made, from dust to 1¼-inch. There are large elevated bins with a driveway under them, south of the quarry. (See Pl. XVI, B.) The product is used in Lancaster for the most part and is delivered by truck and by the Conestoga Traction Co., whose line runs just north of the quarry.

PLATE XVI



A. Working face of Stoner quarry 1 mile northeast of Lancaster, in thick-bedded laminated Conestoga limestone.

B. Crushing plant at Stoner quarry.

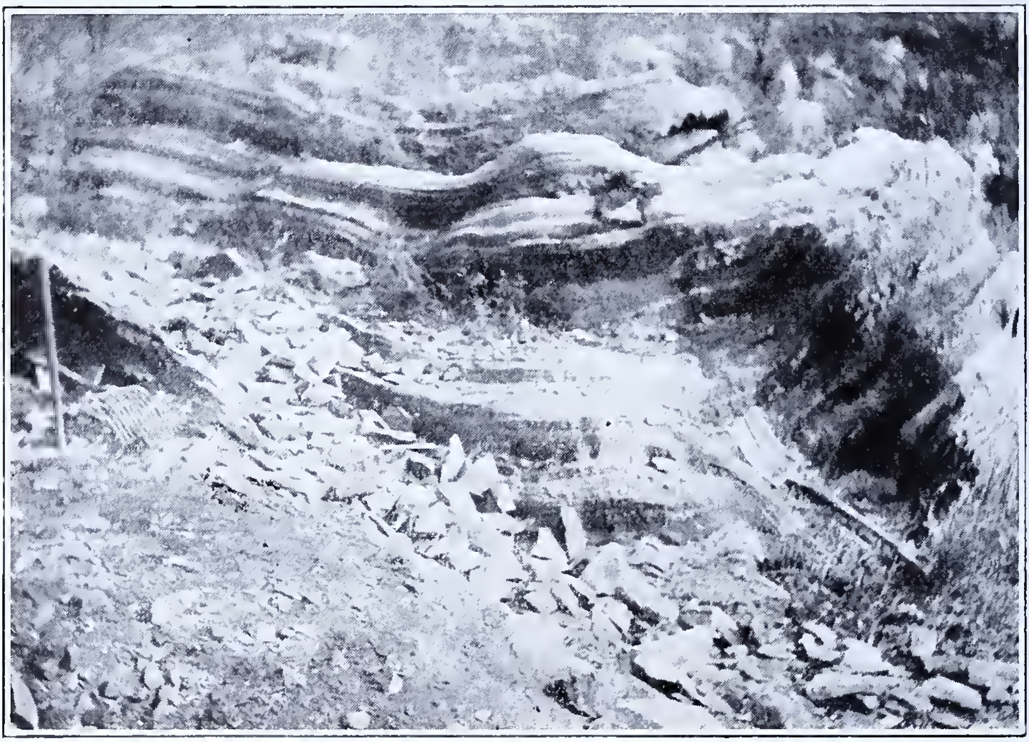
The Conestoga Traction Co. operates at intervals an old quarry (No. 22) north of the C. D. Stoner quarry. It is in ribbed and banded Conestoga limestone and is used for crushed stone. This quarry furnished the blocks for the piers of the Pennsylvania Railroad bridge over Conestoga Creek just south of the Lancaster water-works. These blocks are 5 by 2 by 1½ feet and are built into a four-arch stone bridge (Pl. XXIII, A.) Blocks of this ribbed stone were used by the railroad in retaining walls at the Pennsylvania Railroad station at Lancaster and in bridges and culverts in and around the city. Churches and other buildings have also been built of this strikingly marked stone. (See Pl. XIV, B.)

The J. B. Heidig quarry (No. 23) is just east of the city limits of Lancaster. It is 1,000 feet long and irregular in width. The rock is thin-bedded slaty limestone (see Pl. XVII, A), much folded and variable in character, and only selected portions of the quarry face are worked. Although the quarry covers a wide area its depth is not more than 20 feet. It is equipped with a gyratory crusher, pan-elevator, screens, and bins, which are near the center of the quarry. (See Pl. XVII, B.) They are operated by electricity, and the rock from the quarry is delivered to the crusher by horse-drawn carts. A Byers Bear Cat shovel operated by electricity is used to remove overburden and load the carts. The product is crushed stone, and a plant has been installed at the quarry to use the powdered stone in making hollow concrete blocks for building. Considerable new machinery was added in 1926.

The Conestoga Traction Co. owns a quarry (No. 24) along its line to Rocky Springs Park in an oxbow of Conestoga Creek southeast of Lancaster. There are two openings, the southern one in blue crystalline limestone in beds 3 to 6 feet thick and the northern one in hard siliceous thick-bedded dolomite. A crusher, pan-elevator, screens, and bins are located at the northern quarry. The southern quarry has a face 30 feet high and 30 feet wide and is cut into the hill about 40 feet. It is worked by hand, and the large blocks taken out are loaded on tram-cars and hauled up an incline to the crusher.

Two active quarries (No. 25) on the east side of the Rocky Springs oxbow, west of an old mill dam on property owned by Martha Davis, are called the City Mill quarries. The smaller quarry, which lies to the north, has been operated by J. D. Kendig for building stone, and the southern quarry has been worked for crushed stone. The J. W. Brenner Co., R. D. 6, Lancaster, is operating these quarries and has installed a crusher, pan-elevator, screens, and bins at the northern quarry. Rock is hauled from the southern quarry to the crusher in three Ford trucks. The crusher is a Champion jaw crusher, No. 4½, and the entire equipment is run by electric motors installed in 1925. The southern quarry is 1,000 feet long from north to south and is

PLATE XVII



A. Folded thin-bedded argillaceous ribbed Conestoga limestone at Heidig quarry, 1 mile northeast of Lancaster.

B. Crushing plant at Heidig quarry.

cut 50 to 75 feet westward into the hill, with a 40-foot face. The rock is siliceous limestone in beds 3 to 6 feet thick, infolded with slaty limestone, and is quarried for crushed stone.

The quarry of Deulinger & Johnson (No. 26), 61 North Duke Street, Lancaster, lies west of Conestoga Creek and southwest of quarry 22, just within the Lancaster city limits. It is 200 feet long and has a face 25 feet high on the west side. It is in closely folded thin slaty limestone. Horse-drawn carts haul the stone to the crusher, a Champion No. 4. The quarry is equipped also with pan-elevator and three screens and bins, operated by steam. The product is made into four sizes and is used for road material and concrete.

Quarry 27 is on Conestoga Creek at Engleside, 2 miles southwest of quarry 26, and is operated by Brookmeyer & Goshkey for crushed stone. It is in folded Conestoga limestone of blue ribbed type with calcite veins and well jointed. Electric motors run the pan-elevator and crushers, one of which is a No. 2 Champion and the other a No. 4½ Good Roads. The oversized stone is returned by pipe to the No. 4½ crusher for recrushing. Trucks haul the stone from the quarry to the crusher, and other trucks deliver the crushed stone to the customer.

Two miles to the west, on another curve of Conestoga Creek, is quarry 28, operated by H. R. Miller. R. D. 2, Lancaster. The quarry face is 30 feet high and 15 feet across, and rock is hauled by tramcars to the crusher. An oil-burning engine supplies power for the crushers and pan-elevators. Oversized material is returned from the first to the second crusher. The product is used for road material and concrete. The rock is heavily bedded blue crystalline limestone of the Conestoga limestone.

The West End quarry (No. 29) is on the east side of Little Conestoga Creek south of the Lincoln Highway and has been operated by Clarence D. Stoner for a number of years. The rock is thin-bedded, closely folded slaty blue limestone veined with white calcite and is taken out of the main opening, which extends 200 feet eastward into the hill, in an oval 300 feet across the strike. Quarrying has not cut down below the creek level, and horse-drawn carts haul the quarried rock to the crushing plant on the west side of the creek. There are three Simpson disk crushers with pan-elevators and bins, operated electrically. The crushed stone is shipped by truck. J. C. Budding, of Lancaster, is agent for the stone.

Another quarry (No. 30) operated by Clarence D. Stoner is south of the Lincoln Highway east of Columbia. It is about 500 feet in diameter. Since 1919 the quarry has been cut down to a depth of 50 feet. The rock is blue crystalline limestone or dolomite, massive and horizontal on the north side, where it is chiefly quarried. The northeast end contains folded slaty limestone with limestone breccia above the slaty beds. The plant is operated for crushed stone, and uses electric power.

The three old Strickler quarries are along the north side of Strickler Run, about a mile south of C. D. Stoner's quarry. The quarries are in Conestoga limestone, and the analyses given below show the variability in its composition.

Charles S. Bender, of Millersville, operates a quarry (No. 31) on Little Conestoga Creek 1 mile west of Millersville, near Frantz Mill. The rock is blue crystalline limestone of the Conestoga. It is closely folded, thin bedded, with thin graphitic slaty partings, and infolded with thick-bedded siliceous crystalline limestone. The quarry face is 30 feet high and 100 feet long on the strike and is in a hill

Analyses of Limestone from Lancaster Quadrangle.

	Formation	Map No.	Nearest town	SiO_2	Al_2O_3 and Fe_2O_3	$CaCo_3$	$MgCo_3$	H_2O
1	Beekmantown	Near 9, 10, 11	Manheim	3.38	4.51	52.28	39.35	0.48
2	do	do	do	3.42	2.88	54.23	39.05	.42
3	do	do	do	7.12	1.51	74.42	16.67	.28
4	do	do	do	1.45	.54	86.50	11.15	.36
5	do	do	do	1.62	.29	93.34	4.39	.36
6	do	do	do	5.60	.44	89.17	4.51	.28
7	do	do	do	4.52	.64	88.77	5.75	.32
9	do	do	do	4.08	.58	90.64	4.14	.56
10	do	do	do	2.28	.40	93.24	3.56	.52
11	do	do	do	6.25	.44	87.75	5.16	.20
12	do	do	do	13.96	3.36	57.43	24.73	.52
13	do	Near 15	Mount Joy	2.54	.81	90.00	5.45	--------
14	Conococheague	Near 16, 17	Centerville	7.91	5.82	78.16	--------	--------
15	do	do	do	8.47	2.81	63.54	24.87	--------
16	do	do	do	1.03	1.24	54.84	42.82	--------
17	do	do	do	3.52	1.85	53.54	41.08	--------
18	Ledger	Near 19	Lancaster	1.40	.76	55.01	42.85	--------
19	do		Newtown	.33	.68	55.03	44.05	--------
20	Conestoga	Near 29	Columbia	.40	2.24	56.81	40.23	.32
21	do	do	do	.32	2.18	53.29	43.77	.144
22	do	do	do	.08	.64	53.28	45.28	.72
23	do	do	do	.29	2.14	53.17	44 04	.36
24	do	do	do	.72	2.04	53.19	43.73	.32
25	do	do	do	.78	1.14	68.22	29.08	.48
26	do	do	do	.32	.53	86.24	12.71	.20
27	do	do	do	.24	.31	88.67	10.53	.25
28	do	do	do	.12	.40	83.46	15.70	.32
29	do	do	do	.12	.20	90.8	8.55	.24
30	do	do	do	1.61	.84	92.53	4.66	.36
31	do	do	do	1.38	1.18	90.81	6.15	.148

1-12. Beekmantown limestone, about one-half to 1½ miles south of Manheim, along the tracks of the Philadelphia & Reading Railroad near county bridge. Analyst, J. B. Britton, Pennsylvania Second Geol. Survey, Rept. CCC, p. 272. 1880.

13. Beekmantown limestone, 1 mile south of J. N. Stauffer Bros. quarry on Little Chickies Creek, east of Mount Joy. Analyst, Bethlehem Steel Co., Miller, B. L., Limestones of Pennsylvania: Pennsylvania Top. and Geol. Survey, Bull. M-7, p. 90, 1925.

14-15. Conocheague limestone, 2½ miles east of Mount Joy and one-fourth mile south of Centerville, near quarries of N. S. Newcomer and A. M. Eschelman. Analyst, Bethlehem Steel Co., Idem, p. 90.

16-17. Conococheague limestone, on farms of Henry and Chris Musser, ½ to ¾ miles south of Centerville. Idem, p. 90.

18. Ledger dolomite, Bellemont quarry, west of Lititz road, north of Lancaster. Analyst, Bethlehem Steel Co. Idem, p. 91.

19. Ledger dolomite, half a mile southwest of Newtown, on Chickies Creek. Analyst, Bethlehem Steel Co. Idem, p. 90.

20-29. Conestoga limestone, Strickler quarry, 1 mile southeast of Columbia, half a mile east of the intersection of Strickler Run with the Lancaster & Columbia Railroad and three-quarters of a mile south of Clarence D. Stoner's quarry. Analyst, J. B. Britton. Pennsylvania Second Geol. Survey, Rept. CCC, p. 273, 1880.

30-31. Conestoga limestone, 300 yards northeast of Strickler quarry. Analyst, J. B. Britton. Idem, p. 274.

on the west side of Little Conestoga Creek. It lies east of an older quarry operated for four or five years by Mr. Bender before he opened the present quarry. The old quarry supplied crushed stone for the Millersville-Lancaster road. The present quarry produces crushed stone in four grades. The product is sorted and the graphitic shaly material is eliminated by hand after crushing and screening. The equipment consist of a No. 4 Champion crusher, pan-elevator, and bins. A Fordson tractor supplies power for running the Schramm air compressor and rock drill. The product is shipped by truck for highway work.

SAND.

Uses. Sand is composed largely of quartz grains, with other minerals in varying amounts. The impurities may be clay, lime, or iron. Sand is classed as coarse, medium, or fine and occurs as loose sand which can be dug and screened or as sandstone or quartzite which has to be crushed before screening.

The uses of sand are varied. The most extensive uses are in mortar. plaster, and concrete. in foundries, in filtration plants, and in the manufacture of glass, of which it is the major constituent. It is used also for grinding, in stone-cutting, and for traction sand and chicken grit.

Building sand used in concrete, in mortar, in making limebrick, and for facing concrete blocks should be composed of quartz with but little clay.

Foundry sand includes molding, core, and steel sands. The chief requisites of sand for such purposes are cohesiveness, refractoriness. permeability, and durability. A sand with some binder is needed to hold together the mold when the pattern is removed; hence a molding sand should contain some clay. Iron-molding sands have natural bond. Steel sand, however, which is subjected to a high degree of heat, must contain more than 97 per cent of silica so that it will not fuse or melt when the molten metal comes into contact with it. Such a high silica sand has no natural bond and bonding material must be added to it. A sand containing 75 to 85 per cent of silica can be used as molding sand for iron work, where a lower temperature than in steelmaking is used. Sand used for filter beds must be clean silica in sorted sizes, free from clay, loam, or lime. For glass making a fine white sand composed of angular grains of uniform size and free from iron is the best grade. The value of any sand deposit is measured not only by the quality of the sand but also by the quantity available and the cost at which it can be quarried or dug and marketed.

Active Quarries.

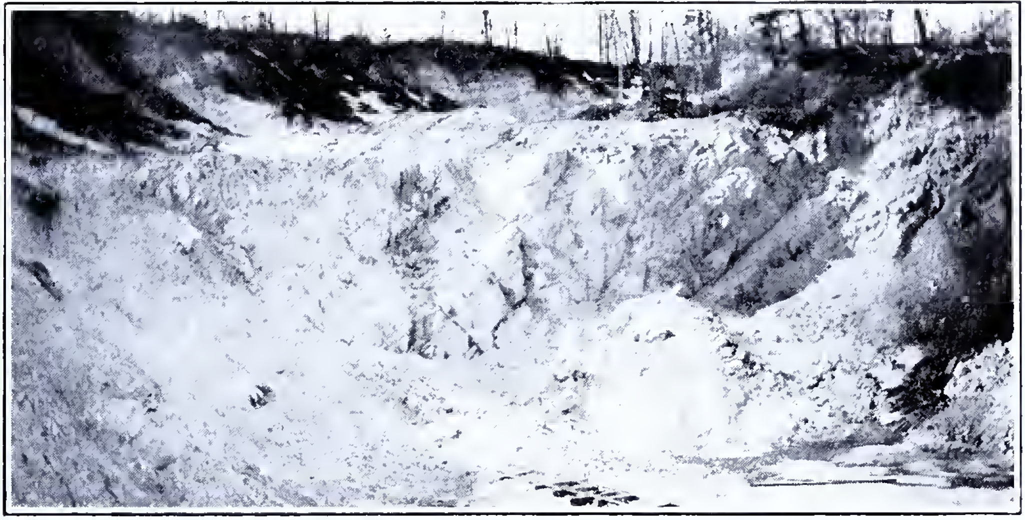
The sand quarries in operation in the Lancaster quadrangle are shown by numbers on the topographic map and described below. The Chickies quartzite yields an excellent building sand and is quarried for this purpose at several places on Chestnut Hill. Certain beds of the formation disintegrate readily and can be used without crushing. The harder masses are crushed. The product is a fine white sand with little iron or clay. The quartzite beds from which most of the sand is derived are in the upper part of the Chickies formation. The outcrop on the steep hillside makes quarry development easy, and there is no trouble with water. There are several of these sand pits in operation north of Mountville.

Burnbright quarry. The westernmost quarry (No. 32) is operated by W. E. & F. G. Burnbright in white crumbly quartzite somewhat stained with iron. A cut 20 feet high has been made in the southward-dipping beds on the upper south slope of the hill. When crushed it is a fine white even-grained sand containing a little mica or magnetite. The sand is shipped by truck to nearby places for building purposes.

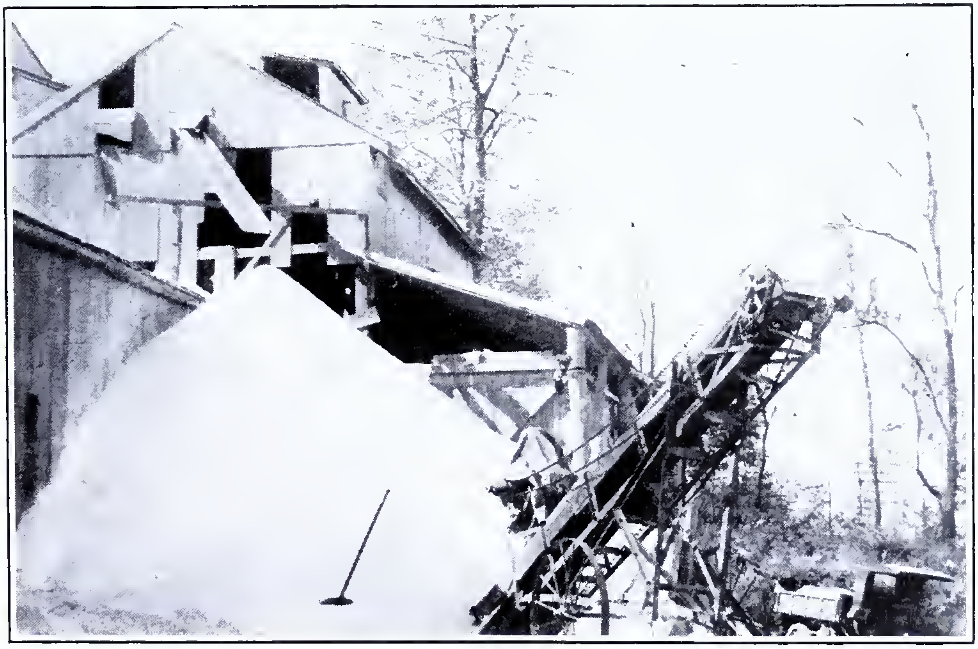
Oyster Point Sand Company. Quarry 33, the largest sand quarry in the area, is at Oyster Point, at the northeast end of Chestnut Hill south of the Marietta road, 2 miles west of Rohrerstown. It is operated by the Oyster Point Sand Co. (H. D. Bowers & Sons). (See Pl. XVIII, A.) The rock worked is a hard fine white quartzite composed of somewhat angular fine quartz grains, cemented by quartz. There are also in the quarry layers of sericitic quartzite and a 1-foot bed of coarser-grained pebbly quartzite. The beds strike N. 30° E. and show anticlinal structure in the quarry. The overburden, which is only 3 feet thick, is composed of loose clayey sand with quartzite fragments, and this sand can be used for mortar in laying bricks. The quarry is equipped with a Bay City shovel No. 52, electrically operated. There is a tram incline to the New Holland jaw crusher, and dry pan to crush the sand before it passes over the screens. Two grades of sand are produced, and there are ample storage bins (Pl. XVIII, B).

The sand is delivered by truck for use in concrete, for general building purposes, and for puddling in steel mills.

Herr quarry. The Herr quarry (No. 34) lies on the south slope of Chestnut Hill between the Burnbright and Oyster Point quarries. It is owned by John M. Herr and operated by his son, Aaron Herr, under the name Mountville Sand Co. The pit is east of an older one which had been worked for 15 years prior to the present working. The rock is a fine white quartzite, with some interbedded slickened ferruginous slate beds. The quartzite is considerably disintegrated but requires



A. Oyster Point sand quarry in crumbly thin-bedded Chickies quartzite. 2 miles west of Rohrerstown.



B. Stock pile and loading machine at the Oyster Point quarry.

blasting. It is crushed in a New Holland crusher and in rolls, and is shipped by truck for use in building.

Other sand pits. A mile east of Kinderhook there is an old quarry (No. 35) owned by Earl Greider, of Ohio, that was operated for sand for several years by Detweiler, Emig & Collins, of York. The quarry was opened along the strike of the quartzite for 200 feet and is about 50 feet across the strike. The dip is 30° S. (See Pl. IV, A.) A section of the rock exposed is given on page 17.

In the southeastern part of Lancaster, 1 mile from the Factory Bridge, several deep pits (No. 36) were formerly operated by Mr. Jacob Betz for building sand. The pits are more than 50 feet deep and are on both sides of the main road, following the strike of the beds nearly east-west. The rocks dip 45° S., and the quarry exposes about 100 feet of thick-bedded, very sandy granular light-gray limestone of the Conestoga formation, which weathers to a crumbly buff sandstone, easily crushed into sand grains. The eastern pit has been worked down into firm quartzitic limestone and has been abandoned. A small amount of sand is still being dug in the western pit.

William H. Hull has opened a small pit (No. 37) on the Lebanon-Manheim road just north of the Lancaster County line. It is in coarse sandstone of the New Oxford formation which has been baked and hardened by the intrusion of Triassic diabase. The material is used for making a hand cleaner and for valve grinding, building sand, and chicken grits. Another product, largely of residual clay, is prepared as a beauty clay.

CLAY.

Uses. Clay is the residuum of decomposition of certain rocks and is composed of kaolinite with quartz and iron compounds as impurities. Kaolinite or kaolin is the chief product of the decay of feldspar, hence also of the weathering of pegmatite. Clay is residual from feldspathic sandstone, shale, and limestone, as well as of igneous rocks such as granite and gabbro. Kaolin is used largely in the manufacture of pottery, china, and paper; other clay is used in the manufacture of brick, tile, and refractory products, and also in the manufacture of linoleum, rubber, cement, chemicals, and artificial abrasives.

The clays of the Lancaster area are residual clays and are used for making brick. These clays are derived chiefly from two formations, calcareous beds in the Antietam quartzite and highly argillaceous beds in the Conestoga limestone. The active clay pits are shown on the map and described below.

Mountville Brick Co.

The Mountville Brick Clay Co. owned by J. C. Budding Co., 142 North Queen Street, Lancaster, has its plant (No. 38) in Mountville, south of the Columbia branch of the Pennsylvania Railroad. The clay is derived from disintegrated quartzite and phyllite of the Antietam formation and is partly residuum in place and partly wash. The quarry (Pl. XIX, A) is a cut 1500 feet long in the upper ferruginous beds of the Antietam, near its contact with the overlying Vintage dolomite on the north side of the Mountville anticlinal hill. The quarry is cut into the hill as much as 500 feet in the center, where hard rock was encountered.

The present operations are at the west end of the cut, which has a face about 50 feet high. The beds in the quarry face strike N. 40° E. and dip 5° NW., and the schistosity trends south. From the upper level is dug gray clay mixed with much surface wash, which is used for making ordinary red brick. From the lower level a highly ferruginous clay is obtained, which is derived from the fossiliferous ferruginous layer near the top of the Antietam. From this clay is produced rich maroon and chocolate-colored brick which is in great demand for fine homes. The clay is dug by an electric shovel and is carried in horse-drawn carts to the plant, where it is ground and pulverized. From the cutting house the bricks pass automatically to eight drying houses, where they are heated from below by coal furnaces. After drying the bricks are burned in circular down-draft kilns, of which there are seven (Pl. XIX, B), in operation at this plant. The kilns have eight firing holes and an outside chimney for the draft. The capacity of each is 72,000 bricks. They are burned for six to eight days, according to the kind of bricks made. A new down-draft kiln was built in 1926, which is elongated domeshaped instead of round. This kiln is equipped with seven cross arches with two firing holes to an arch, with chimneys on the sides. The bricks produced range in color from dark chocolate-brown to maroon and bright red. Atlantic brick oil is used in making smooth-faced brick, but rough brick made by the wire cutting process is the chief product. This brick, especially in the darker shades of red, is very popular for houses in the vicinity of Mountville, Lancaster, York, and Harrisburg and is shipped to many distant points.

Lancaster Brick Co.

The Lancaster Brick Co's. plant (No. 39) is south of the Columbia branch of the Pennsylvania Railroad, three-quarters of a mile west of the junction with the main line to Harrisburg. It lies just south of the Harrisburg road 2 miles northwest of Lancaster. The plant was opened in 1920. The clay used is yellow-brown, is fairly uniform in character, and is derived from the disintegration of argillaceous Conestoga limestone. The larger clay pit is in a side

PLATE XIX

A. Clay pit of Mountville Brick Co., Mountville. On the north flank of an anticline of disintegrated Antietam quartzite.

B. Down draft circular kilns and plant of Mountville Brick Company.

valley of Little Conestoga Creek; the top clay soil has been stripped from several acres to a depth of 4 or 5 feet. A smaller pit west of the plant yields a redder clay which is mixed with the yellow. The clay is dug with a large electric shovel and a smaller Bay City dredge. The clay is hauled by tramcars, operated by a gasoline engine, to an incline up which the cars are drawn by cable to the grinding house. The grinding house (Pl. XX, A) is equipped with Chamber Bros. conical rolls, one of which is corrugated. These rolls crush the clay to fine particles, and after screening it is carried up a 300-foot incline by a rubber conveyor belt to the molding room or discharged in an open-air shed, where the excess clay is stored. In molding the clay is mixed with water in a pug mill, which thoroughly churns it before it passes into the 42-inch special Arnold Creager brickmaking machine made by the Lancaster Iron Works. The bricks are dried by steam for 12 hours in the two drying houses, which are long sheds with metal racks under which there are steam pipes with exhaust fans at the top (Pl. XX, B). Their capacity is 60,000 bricks a day. The five kilns are of the up-draft type and have 12 arches each. The bricks are piled checker-board style on the floor with gratings between for the updraft. These drafts are connected with the firing holes at each side. After the kiln is filled the opening is walled up and covered with clay before the bricks are burned. Soft coal is used, and the bricks are burned three days and three nights. The product consists of common, salmon, and colonial brick.

Wise Bros. Brick Co.

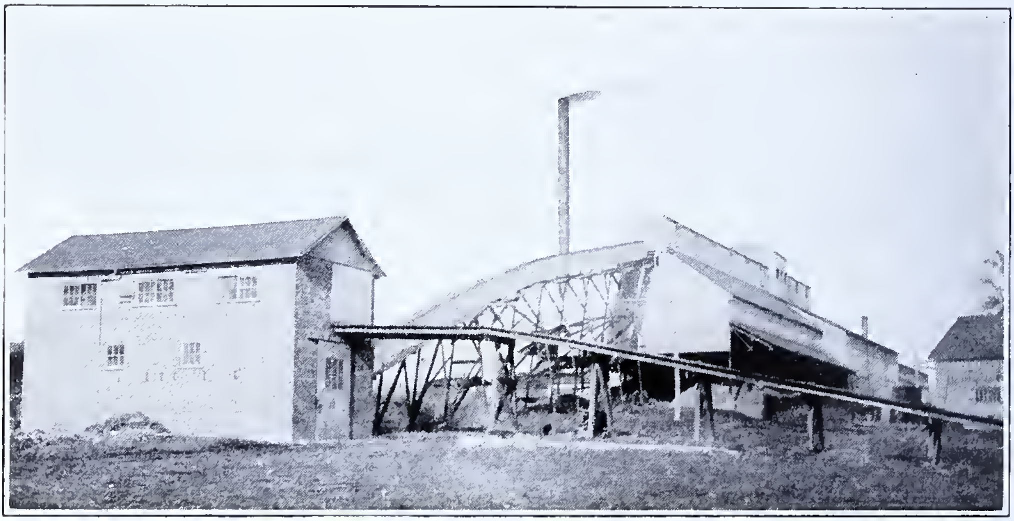
The C. Wise & Bros. Manufacturing Co. operates a brick plant (No. 40) within the city limits of Lancaster south of the Millersville road. The clay is residual from the Conestoga limestone. It is obtained by surface stripping over a large area south of the plant and is hauled by trucks from the pit to the plant. It is ground wet and mixed in a pug mill before going into the brick machines. The steam drier holds 20,000 bricks on plate racks. There are three kilns—one 7-arch and two 6-arch, of up-draft type. Soft coal is used in firing the kilns and in the boiler room.

BUILDING STONE.

Several kinds of rock in the Lancaster area have been used for building stone. Limestone was used widely in the old days for this purpose. The Chickies quartzite was quarried for foundations, steps, and sills, and to some extend for houses.

The thicker-bedded sandstone of the Triassic has been locally quarried for building stone, and in the northern part of the quadrangle there are many old houses and barns built of this red or reddish-brown rock. Although the color is pleasing, the rock is soft and often scales badly on being exposed to the weather.

PLATE XX



A. Grinding shed, elevator, and plant of Lancaster Brick Co., southwest of Dillerville.

B. Drying sheds and plant of Lancaster Brick Co.

Phyllite in the Antietam formation is quarried for building stone in the hill south of Mountville. This quarry (No. 40) is owned and operated by A. R. Shaffer. The rock possesses a marked nearly vertical schistosity along which it breaks readily into slabs by using a crowbar. It is a greenish-gray sparkling phyllite and makes a pleasing building stone if properly dressed and laid.

A new opening (No. 42) for building stone is the Walter B. Kendig quarry just east of Lancaster and south of the J. B. Heidig crushed-stone quarry (No. 23). The rock is Conestoga limestone of the banded blue crystalline type with slickensided slaty partings. It strikes N. 60° E. and dips 75° S. Blocks have been taken out from an opening about 25 feet square. The quarry has a drilling machine and a gasoline pump for removing water. The slabs are used for buildings in Lancaster.

The northerly quarry at the old City Mill (No. 43) has been operated by J. D. Kendig for building blocks. The rock is the Conestoga limestone with a dip of 70° S. During 1925 the quarry supplied building stone for two houses in Lancaster. The quarry is now operated by J. M. Brenner. It supplied stone for the old City Mill and adjoining houses (Pl. XXI, A). The old Factory Bridge over Conestoga Creek, 1½ miles to the south, is also built of Conestoga limestone of similar type and is typical of the older stone bridges of the region. (See Pl. XXI, B; also Pl. XIV, B, and Pl. XXIII, A.)

IRON ORE (Limonite).

Limonite, or brown hematite as it is commonly called, is a chemical combination of iron, oxygen, and water. It is in general brown, but there are yellow and red varieties. It has been extensively mined in the Lancaster quadrangle near Silver Spring and at Copenheffer, on the north side of Chestnut Hill. The iron ore occurs chiefly along the contact of the ferruginous Antietam quartzite and overlying Vintage dolomite, also along faults in the Lower Cambrian arenaceous rocks, the Vintage dolomite, and younger limestones. These brown ores were precipitated from circulating underground waters containing iron in solution which found passage along contacts of limestone and other rocks or along fault planes. The ores associated with the Vintage-Antietam contact were probably derived from iron originally deposited in the rocks at this horizon in the form of carbonate or some other readily soluble mineral and set free on the weathering of the rocks. The upper beds of the Antietam are everywhere weathered at the surface to a highly rust-stained porous rock, indicating the former presence of iron carbonate.

These deposits were worked 40 to 60 years ago, and a description of the ore and mines is given in Report CCC of the Second Geological

PLATE XXI

A. City mill dam on Conestoga Creek and retaining structure built of Conestoga limestone, 1 mile southeast of Lancaster.

B. Piers of old Factory Bridge over Conestoga Creek, 1 mile southeast of Lancaster, built of Conestoga limestone.

Survey of Pennsylvania, pages 203-320. At the present time the mines are all inactive, because of inability to compete with lower-priced ore from other areas. They are indicated by numbers on the map and described briefly below.

The Chestnut Hill mines (No. 44), southwest of Silver Spring, were the largest mines in the area. They lie north of the west end of a low anticline of Antietam quartzite at the contact with the overlying Vintage dolomite. They are some distance southeast of a diagonal fault which extends from a point near Silver Spring S. 65° W. through Ironville, but the ore is probably in no way related to the fault. Mining was begun as early as 1820 in the northeast end of the banks by E. B. Grubb.[1] In 1877 the Chestnut Hill banks were divided between three owners: the heirs of E. B. Grubb took the northeastern part, C. B. Grubb the central part, and the Chestnut Hill Iron Ore Co. the southwestern part.

The ore was chiefly brown hematite wash ore, with hard concretionary masses in the lower part, and quartz was plentiful throughout. The ore lay in beds or stringers. The old openings, 80 to 100 feet deep, extend southwestward for half a mile, forming a horseshoe around the western end of the anticline of Antietam quartzite. (See Fig. 10). At present the northeastern ore pit is filled with water and

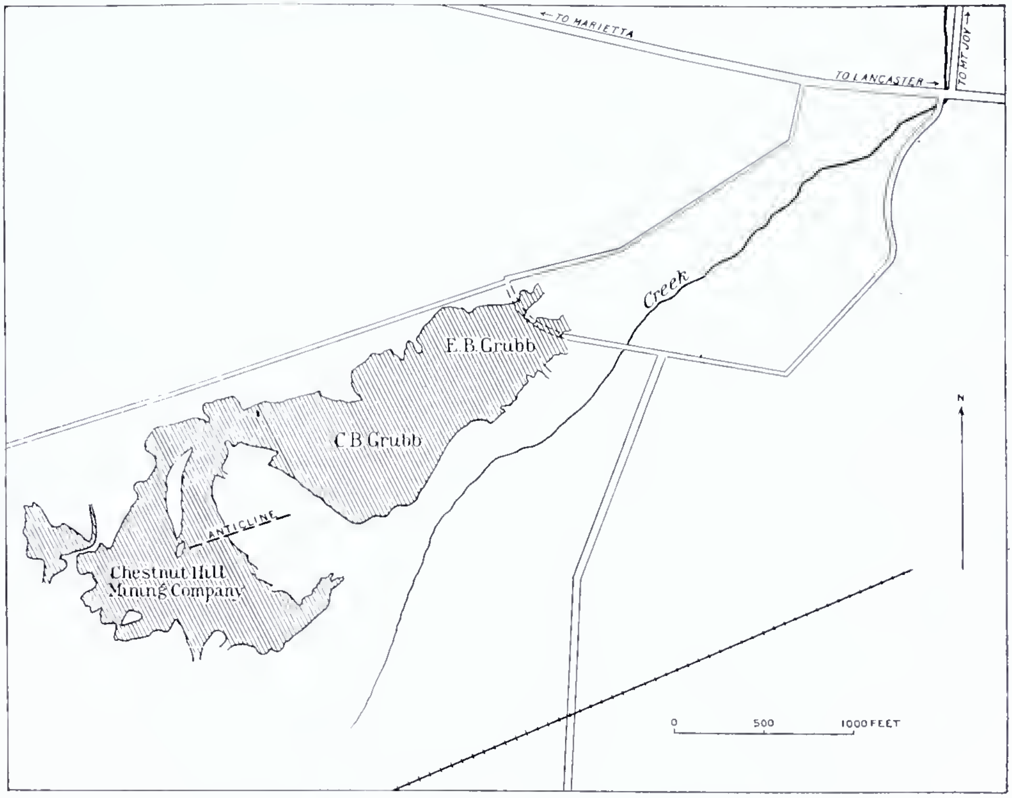


Fig. 10. Chestnut Hill ore banks.
From Pennsylvania Second Survey Rept. CCC.

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[1] Pennsylvania Second Geol. Survey. Rept. CCC. pp. 210-216. 1880.

PLATE XXII

A. Grubb Lake, filling old workings of Chestnut Hill iron banks. 1 mile southwest of Silver Spring.

B. Frantz grist mill on Little Conestoga Creek 1 mile west of Millersville.

called Grubb Lake. (See Pl. XXII, A.) A large amount of ore was removed in the years from 1863 to 1880, but since then the property has stood idle. The ore was shipped to the E. Haldeman Co. and Chickies Iron Co. and the St. Charles and Henry Clay furnaces at Chickies, 3 miles north of Columbia.

The following analyses[1] represent ore from the Chestnut Hill and Silver Spring mines:

Analyses of iron ore from Chestnut Hill and Silver Spring mines.
(Analyst, A. S. McCreath)

	Chestnut Hill	Silver Spring
Metallic iron	53.500	45.200
Metallic manganese	1.015	1.101
Sulphur	.003	.003
Phosphorus	.263	.048

The Heiss mine (No. 45) was a small pit south of the Chestnut Hill property. The Silver Spring mine (No. 46), operated by Haldeman & McCormick and E. B. Grubb in 1863 to 1874, adjoined the Grubb property on the north. The excavation was perhaps 60 feet deep and covered an acre. The ore was limonite and was shipped to the Chickies Iron Co's. furnace. The deposit lies adjacent to the diagonal fault through Ironville and was probably determined by the fault.

Another series of iron mines was located near Copenheffer, on the north flank of the Chestnut Hill anticline. The same kind of brown limonite ore was mined from these ore banks in the period preceding 1890. The Copenheffer ore bank (No. 47) was south of Chickies Creek and north of the railroad. The Sherks ore mine (No. 48) lies south of the road, one-eighth of a mile south of the Copenheffer mine, and for about ten years produced 10,000 tons a year. A large pit filled with water marks the site of the operations. It is in Conococheague limestone near the fault contact with Harpers phyllite. The ore pit of R. Garber (No. 49) adjoins it to the east and was a small working.

The John Hertzler mine (No. 50) lies in Ledger dolomite a quarter of a mile north of the fault on the north flank of the Chestnut Hill anticline. The ore, however, like that in the other mines, was probably concentrated by ore-bearing solutions passing along the fault, some of these solutions penetrating the adjacent limestone and replacing the lime with iron.

Other iron ore pits east of the two groups already mentioned are located along faults in limestone. The largest one (No. 51) is a mile northwest of Dillerville, at what was called Oreville. Like the other iron mines, it has long been abandoned. It is on the property of

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[1] Idem, p. 219.

David Graybill, of Lititz, who with his father operated the mine for many years.

LEAD AND ZINC ORE.

The only lead and zinc mine in the area is the Bamford mine (No. 52), near Bamford, 3 miles southeast of Landisville. The mine was opened in 1855, and the last work was done there in 1883. A history of the mine has recently been given by Miller.,[1] and the deposit was previously fully described by Frazer who quotes a statement of the history of the mine, by E. G. Spilsbury, Superintendent of the works till 1877[2]. The ore above water level was calamine and cerusite; that below water level was sulphide of zinc and lead. It occurs in two veins with brecciated limestone hanging walls. The veins strike N.74°E. and dip 72°NW. The ore pinched out at a depth of about 110 feet.

Surface evidence at the site of the mine is so slight that nothing can be added to the data already published, except that the limestone in which the veins occur is the Ledger dolomite of Lower Cambrian age instead of Silurian as has been stated. It overlies fossiliferous Lower Cambrian Kinzers shale, and underlies Elbrook limestone of Middle Cambrian age.

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[1] Miller, B. L., Lead and zinc ores of Pennsylvania: Pennsylvania Top. and Geol. Survey. Bull. M-5, pp. 49-53. 1924.

[2] Frazer, Persifor, Jr.: Pennsylvania Second Geol. Survey Rept. CCC. p. 55, 196-203. 1880.

Active quarries.

Number on map	Owner or operator and address	Product	Rock formation
1.	Isaac E. Stauffer, R. D., Lititz	Crushed stone	Beekmantown
2.	C. P. Risser, owner; Anderson Shoemaker, operator, R. D., Lititz	do	do
3.	John Seibert, R. D., Lititz	do	do
4.	Theo. L. Forney, Lititz	do	Conococheague
5.	Al. Shenk, Lititz	do	do
6.	Elmer H. Hershey (formerly "Rome" quarry of Aaron Long), Lititz	do	do
7.	J. B. Bucher, (formerly Ramoth Lime & Stone Co.), 48 North 9th St., Lebanon	Crushed lime	do
8.	Charles B. Winter, Manheim	Crushed stone	Beekmantown
9.	Wm. Gantz, Manheim	Lime	do
10.	A. F. Metzgar, Manheim	Crushed stone	do
11.	J. L. Kauffman, R. D. 2, Box 132, Manheim	Lime	do
12.	Thomas A. Erb, Lititz	Crushed stone and lime	do
13.	Abraham E. Binkley, Neffsville	Crushed stone	Conococheague
14.	Binkley & Ober, East Petersburg	do	do
15.	J. N. Stauffer & Bro., R. D. 2, Mount Joy	do	Beekmantown
16.	N. S. Newcomer, Mount Joy	do	Conococheague
17.	A. M. Eshleman, Landisville	do	do
18.	I. S. Siegrist, R. D., Mount Joy	do	do
19.	Bellemont quarry, Aaron B. Hess, owner, Harrisburg	Crushed stone and lime	Ledger
20.	Dolomite Products Co., Brenneman Bldg., N. Duke St., Lancaster	Dolomite products	Ledger
21.	C. D. Stoner, Columbia	Crushed stone	Conestoga
22.	Conestoga Traction Co., Lancaster	Crushed stone	do
23.	J. D. Heidig, Lancaster	do	do
24.	Conestoga Traction Co., Rocky Springs quarry	do	do
25.	City Mill quarry, J. M. Brenner & Co., R. D. 6, Lancaster	Building and crushed stone	do
26.	Denlinger & Johnson, 61 North Duke St., Lancaster	Crushed stone	do
27.	Brookmeyer & Goshkey, Ingleside, R. D. 7, Lancaster	Building and crushed stone	do
28.	H. R. Miller, R. D. 2, Lancaster	do	do
29.	Clarence D. Stoner, West End quarry, J. C. Budding, agent, Lancaster	do	do
30.	Clarence D. Stoner, Columbia quarry, Columbia	do	do
31.	Charles S. Bender, Millersville	Crushed stone	do
32.	W. E. & F. G. Burnbright, Lancaster	Building sand	Chickies quartzite
33.	H. D. Bowers & Sons, Oyster Point Sand Co., Lancaster	Building sand and in steel mills	do
34.	John M. Herr, owner; Aaron Herr, operator, Mountville Sand Co.	Building sand	do
35.	Earl Greider, Ohio, owner; formerly operated by Detweiler, Emig & Collins, York	do	do
36.	Jacob Betz, R. D., Lancaster	do	Conestoga limestone
37.	Wm. H. Hull	Sand products	Triassic sandstone
38.	J. C. Budding Co., Lancaster	Building brick	Antietam quartzite
39.	Lancaster Brick Co., Lancaster	do	Conestoga limestone
40.	C. Wise & Bros., Lancaster	do	do
41.	A. R. Shaffer, Mountville	Building stone	Phyllite from Antietam quartzite
42.	W. B. Kendig, Lancaster	do	Conestoga limestone
43.	J. D. Kendig, Lancaster	do	do

Inactive Iron (Limonite) Mines.

44. Chestnut Hill ore banks;
    a. E. B. Grubb,
    b. C. B. Grubb,
    c. Chestnut Hill Iron Ore Co., Ironville
45. Heiss mine, Ironville
46. Silver Spring mines, Silver Spring
47. Copenheffer mines, Copenheffer
48. Sherks mines, Copenheffer
49. R. Garber mine, Copenheffer
50. John Hertzler mine, north of Copenheffer
51. David Graybill, Oreville

WATER RESOURCES.

Precipitation.

The average annual rainfall in the eastern Piedmont region, which includes the Lancaster area, is about 44 inches, almost equally distributed throughout the four seasons. There is a variation, however, from 32 inches in the driest year to 73 inches in the wettest year. In the Lancaster quadrangle the rainfall for wet years is not above 55 inches.

Run-off.

At present no data are available on the volume of water flowing in the streams of the Lancaster quadrangle, but a report which will give such information is in preparation by the United States Geological Survey. A report on the hydrography of the Susquehanna drainage basin[1], of which this area is a part, gives much valuable information about this general region. A gaging station is located at McCalls Ferry on the Susquehanna 8 miles south of the mouth of Conestoga Creek and 12 miles south of the Lancaster area. Measurements of the flow of the Susquehanna were made from 1902 to 1904, prior to the building of the dam at Holtwood, from five gaging stations located above and below the dam site.

Water Power.

The streams of the Lancaster quadrangle flow in rocky channels and have rather steep grades. Water power, obtained by the construction of low dams, usually of stone, has been utilized in the past for gristmills. These dams are numerous on Conestoga Creek and its tributaries, chiefly Little Conestoga and Hammer creeks, and on Chickies Creek.

Many of these gristmills are still active and use water power, but some of them have installed electricity and are operated for other purposes than grinding of grain. At Binkleys bridge there is an old gristmill which was formerly operated by power developed on Conestoga Creek. The mill is now owned by the Consumers Box Board Paper Co., of New York City which makes tissue paper, using electric motors, the water power no longer being used. The power of Chickies Creek is used at Centerville in a crushed-stone plant of the N. S. Newcomer limestone quarry. (See Pl. XV, A.) An accessory electric motor has been installed but is rarely needed. The John R. Frantz mill, on Little Conestoga Creek west of Millersville, formerly Groff's mill, is a large gristmill operated by water power. (See Pl. XXII, B.) Steam power is used in times of low water. The Flory gristmill, at Shreiner, has also ceased to use water power.

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[1] Hoyt, J. C., and Anderson, R. H., U. S. Geol. Survey Water-Supply Paper 109, 1905.

Municipal Water Supplies.

The cities and boroughs of the Lancaster quadrangle that have a municipal water supply are Lancaster, Columbia, Lititz, Manheim, Mountville, and Mount Joy. The rest of the area derives its domestic supply from wells and springs.

The municipal waterworks of Lancaster (Pl. XXIII, A) is on Conestoga Creek just north of the Pennsylvania Railroad bridge northeast of the city. The first waterworks was built in 1836, and the present pumping plant in 1888. The filtration plant on the same property, built privately in 1906, is now owned by the city. The water is pumped from Conestoga Creek through two 42-inch pipes and goes to a settling basin. It is passed through scrubbers and sand filters, which have a capacity of 9,000,000 gallons daily. Pumping is done by electricity with eight direct-connected centrifugal pumps. The city has a 1,650,000-gallon filtered-water reservoir at the filtration plant and a twin distributing reservoir on a hill in the eastern part of the city with a capacity of 6,000,000 gallons. A stand pipe 110 feet high and 25 feet in diameter, with a capacity of 400,000 gallons, is utilized for high-pressure service.

In 1924 the average daily consumption was 9,235,629 gallons for a population of 65,000 people. Some of this water used outside of the city is supplied by the Manheim Township Water Co. and the West End Water Co., which respectively supply an area north of the city on the Lititz road and an area west of the city near the Lincoln Highway.

Columbia also takes its water from a surface supply. Its water company, incorporated in 1823, has 16-inch intake pipes in Susquehanna River northwest of the Lancaster quadrangle. The water after being pumped into settling tanks is filtered and pumped into a covered reservoir three-quarters of a mile north of the borough, also outside the quadrangle. The average daily consumption is about 726,000 gallons. The Pennsylvania Railroad at Columbia pumps 125,000 gallons daily from Susquehanna River for use of the railroad roundhouse and shops.

Mount Joy, which like Columbia is partly in the Lancaster and partly in the Middletown quadrangle, takes its water from Little Chickies Creek half a mile north of the borough line. The water supply plant was built in 1874, and the pumps are operated by water power from a dam on the stream when there is sufficient water. A 50-horsepower gasoline pump supplements the water power. The reservoir is a quarter of a mile west of the creek. The water company supplies about 2,500 persons, and the average daily consumption is 500,000 gallons.

PLATE XXIII

A. Lancaster waterworks on Conestoga Creek, and the Pennsylvania Railroad bridge, constructed of large blocks of ribbed Conestoga limestone from nearby quarry.

B. Lititz Spring and municipal water tower of the town of Lititz.

The Manheim Water Co., incorporated in 1884, supplies Manheim Borough from Rife Run. The pumping plant is just west of the borough limit, and the water is pumped to a 750,000-gallon reservoir on a hill north of the town. The water is soft and comes from an area underlain by shale.

The Philadelphia & Reading Railroad pumps 6,000 gallons daily from Chickies Creek at Manheim and takes water from a well in Beekmantown limestone at Lancaster Junction.

Both Lititz and Mountville get their water from springs and wells. The noted Lititz Springs (Pl. XXIII, B) are located in a park in the city owned by the Moravian Church. They flow out of limestone into a large pool which drains eastward through the park and the town into Lititz Run. About 300 yards west of these springs is the municipal waterworks, built in 1893. It gets water from a dug well 35 feet deep. and an electric pump forces water into a 150,000-gallon standpipe near by. Its capacity is about the average daily consumption of the borough. Most of the industrial plants of the town have their own artesian wells. The water obtained is hard.

Mountville derives its water supply from a series of four springs and nine driven wells in Chestnut Hill, 1 mile northwest of the borough. The springs are in Harpers phyllite, just east of a normal fault which trends N. 50° E. The wells are 250 to 360 feet deep and are in an east-west line in a small ravine. In 1925 another well was drilled west of those already producing; the well driller reported quartzite at 300 feet. The water is pumped into two near-by reservoirs by a 24,000-gallon Barry & Zecher deep-well pump with a 3-horsepower gasoline engine. It flows by gravity through an 8-inch main to the distributing mains of the borough.

At Copenheffer the Philadelphia & Reading Railroad obtains a 5,000-gallon daily supply from a spring on the north face of Chickies Hill, south of the station.

The auxiliary pumping plant of the Lebanon waterworks is on Hammer Creek in the northern part of the Lancaster quadrangle. The water is pumped over the divide into the impounding reservoirs, 3 miles to the north, in Lebanon County, at an altitude of 600 feet. The pumps were formerly run by steam, but in 1926 electricity was installed.

Springs.

Many of the springs in the Lancaster quadrangle issue along faults. Among the conspicuous springs of this class are the series in a pleasure park near Penryn Station and a spring 2 miles west of Mount Hope on the same fault. A spring in a hollow in the Cocalico shale south of Manheim is near a north-south fault; another spring with good flow on the north side of Kissel Hill, east of the

Lititz pike, is on a fault that drops the Cocalico shale into contact with the Conococheague limestone. Springs occur southeast and west of Landis Valley and north of Binkley on east-west faults. Along the fault northeast of Centerville there is a series of springs in the Conococheague limestone. Silver Spring was named from the spring along the fault that runs west to the edge of the Lancaster area, and there are other springs along the course of this fault.

Although springs are more numerous along faults they are not confined to fault zones but are rather plentiful in the limestones of the area and form a never-failing supply of water for many farm houses. The Lititz Spring (see Pl. XXIII, B) is one of the largest and best known of such springs. There are fewer springs in the Triassic sandstone and almost none in the Cocalico shale.

GLOSSARY.

Because some words in this report may not be familiar to all its readers, the following definitions, prepared by R. W. Stone, are given:

Anticline. A fold or arch of rock strata dipping in opposite directions from an axis.

Argillaceous. Containing clay.

Arkose. A sandstone rich in feldspar fragments.

Augite. A common rock-making mineral, of dark color with considerable alumina and iron.

Biotite. Common black mica.

Brachiopod. A class of soft-bodied shell-fish with two shells hinged together, symmetrical to the center of the hinge.

Breccia. Rock made of angular fragments cemented together.

Calcareous. Consisting of or containing lime.

Calcite. A common lime mineral, contains 56 per cent lime.

Calamine. A zinc mineral.

Carbonate. A compound formed by the union of carbonic acid with a base.

Cephalon. The head shield of a trilobite.

Cephalopod. The most highly organized class of mollusks, including the octopus and squid.

Cerussite. A lead carbonate.

Chert. An impure form of silica.

Chloritic. Containing chlorite, a green iron-aluminum silicate.

Cleavage. A tendency of rock to split along definite, parallel, closely spaced planes which may be highly inclined to the bedding planes.

Conglomerate. A mixture of rounded pebbles or boulders and sand cemented together into a rock.

Cordierite. A magnesium-iron-aluminum silicate sometimes used as a gem.

Crinoid. An animal related to the star-fishes but fastened to the sea bottom by a stalk.

Crystalline. Having the nature of a crystal.

Diabase. A dark igneous rock usually occurring in dikes or intrusive sheets. Erroneously called black granite.

Dike. A long and relatively thin, nearly vertical body of igneous rock which, while in a state of fusion, entered a fissure in older rocks and there chilled and solidified.

Dip. The angle at which beds or strata are inclined from the horizontal.

Dolomite. A limestone that carries a considerable proportion of magnesium.

Epidote. A green mineral containing lime, aluminum, and iron.

Fault. A break in the continuity of the body of rocks attended by a movement on one side or the other of the break so that what were once parts of one continuous rock stratum or vein are now displaced.

A normal fault is one in which the hanging wall has been depressed relatively to the foot wall.

A reverse fault or overthrust is one in which the hanging wall has been raised relatively to the foot wall.

Feldspar. A general name for a group of abundant rock-forming minerals, containing soda, potash, or lime, and alumina and silica.

Ferruginous. Containing iron.

Fossiliferous. Containing fossil remains of plants or animals.

Gastropod. A mollusk having a one-piece spirally coiled shell, as snails.

Geosyncline. A great downward bend of the earth's crust.

Graben. A depressed tract of land between two or more faults.

Graptolite. An extinct form of coral-like animal.

Horst. A raised tract of the earth's crust between two or more faults.

Hypostoma. Plate covering the upper lip of a trilobite.

Igneous. Formed by solidification from a molten state, as contrasted with sedimentary.

Ilmenite. An iron-titanium mineral.

Indurated. Hardened.

Intrusive. Said of certain igneous rocks which have when molten penetrated into or between other rocks but solidified before reaching the surface.

Labradorite. A lime-soda feldspar.

Limonite. A brown iron ore.

Lithologic. Pertaining to rock character.

Magma. Liquid molten rock; the molten material from which igneous rocks are formed by solidification.

Magnesian. Containing magnesium.

Metamorphosed. A change produced in the texture or composition of a rock after it has hardened.

Meteoric. Pertaining to atmospheric phenomena.

Micaceous. Containing mica.

Oolitic. Consisting of round grains like fish roe.

Ophitic. A crystalline texture characteristic of some diabase.

Orthoclase. A potash-bearing feldspar.

Ostracod. A small marine shellfish having a bivalve limy shell.

Pegmatite. A very coarse-grained granite.

Phyllite. A thin-sheeted rock intermediate between slate and mica schist.

Porcellanite. Fused shale or clay.

Pseudomorphic. Having the outward form of another species of mineral.

Pyrite. A common mineral composed of iron and sulphur.

Quartz. A common rock-forming mineral composed of silica; usually white or smoky.

Quartzite. A quartzose sandstone that has been more firmly cemented by additional silica.

Rhyolite. A volcanic rock.

Saccharoidal. Having a granular texture resembling that of loaf sugar.

Schist. A crystalline rock that can be readily split or cleaved because of internal parallel structure.

Schistose. Having the nature of schist.

Sedimentary. Formed by deposition of grains or fragments of rock-making material commonly from suspension in water.

Sericite. A talc-like mica occurring in small scales.

Siliceous. Containing abundant silica or quartz.

Sill. An intrusive sheet of igneous rock forced between level or gently inclined beds.

Sphalerite. A zinc-bearing mineral.

Strike. The direction or bearing of the outcrop of an inclined bed or of rock structure on a level surface.

Syncline. A fold in rocks in which the strata dip inward from both sides toward the axis.

Synclinorium. A compound syncline.

Test. The hard outside covering or shell of many invertebrates, as the crab.

Trilobite. An extinct marine crustacean having the body divided lengthwise into three more-or-less distinct lobes.

Tripoli. Rock composed of small fragments of chert.

Unconformity. A break in the continuity of sedimentation sometimes represented by different dips in underlying and overlying strata.

Vitreous. Having the lustre of broken glass.

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U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

PENNSYLVANIA DEPARTMENT OF INTERNAL AFFAIRS
JAMES F. WOODWARD, SECRETARY

TOPOGRAPHIC AND GEOLOGIC SURVEY
GEORGE H. ASHLEY, STATE GEOLOGIST

TOPOGRAPHIC AND GEOLOGIC
ATLAS OF PENNSYLVANIA
LANCASTER QUADRANGLE
SHEET 168 PLATE I

EXPLANATION

⚒ Active quarries or quarries recently operated

× Abandoned or idle quarries

Bd	Building
Cl	Clay
Cr	Crushed stone
Ls	Limestone
Lte	Limonite
Qtze	Quartzite
Sd	Sand
Sh	Shale
Ss	Sandstone

LIST OF QUARRIES

LIMESTONE

1. Isaac E. Stauffer
2. C. P. Risser, owner
   A. Shoemaker, operator
3. John Seibert
4. Theo. L. Forney
5. Albert Shenk
6. Elmer H. Hershey
7. J. B. Bucher
8. Chas. B. Winters
9. Wm. Gantz
10. A. F. Metzgar
11. J. L. Kauffman
12. Thomas A. Erb
13. Abraham E. Binkley
14. Binkley & Ober
15. J. N. Stauffer & Bro.
16. N. S. Newcomer
17. A. M. Eshleman
18. I. S. Siegrist
19. J. C. Budding Co.
20. Dolomite Products Co.
21. C. D. Stoner
22. Conestoga Traction Co.
23. J. B. Heidig
24. Conestoga Traction Co.
25. J. M. Brenner Co.
26. Denlinger & Johnson
27. Brookmeyer & Goshkey
28. H. R. Miller
29. C. D. Stoner
30. C. D. Stoner
31. C. S. Bender

SAND

32. W. E. & F. G. Burnbright
33. H. D. Bowers & Sons
34. John M. Herr
35. Earl Greider
36. Jacob Betz
37. W. H. Hull

CLAY

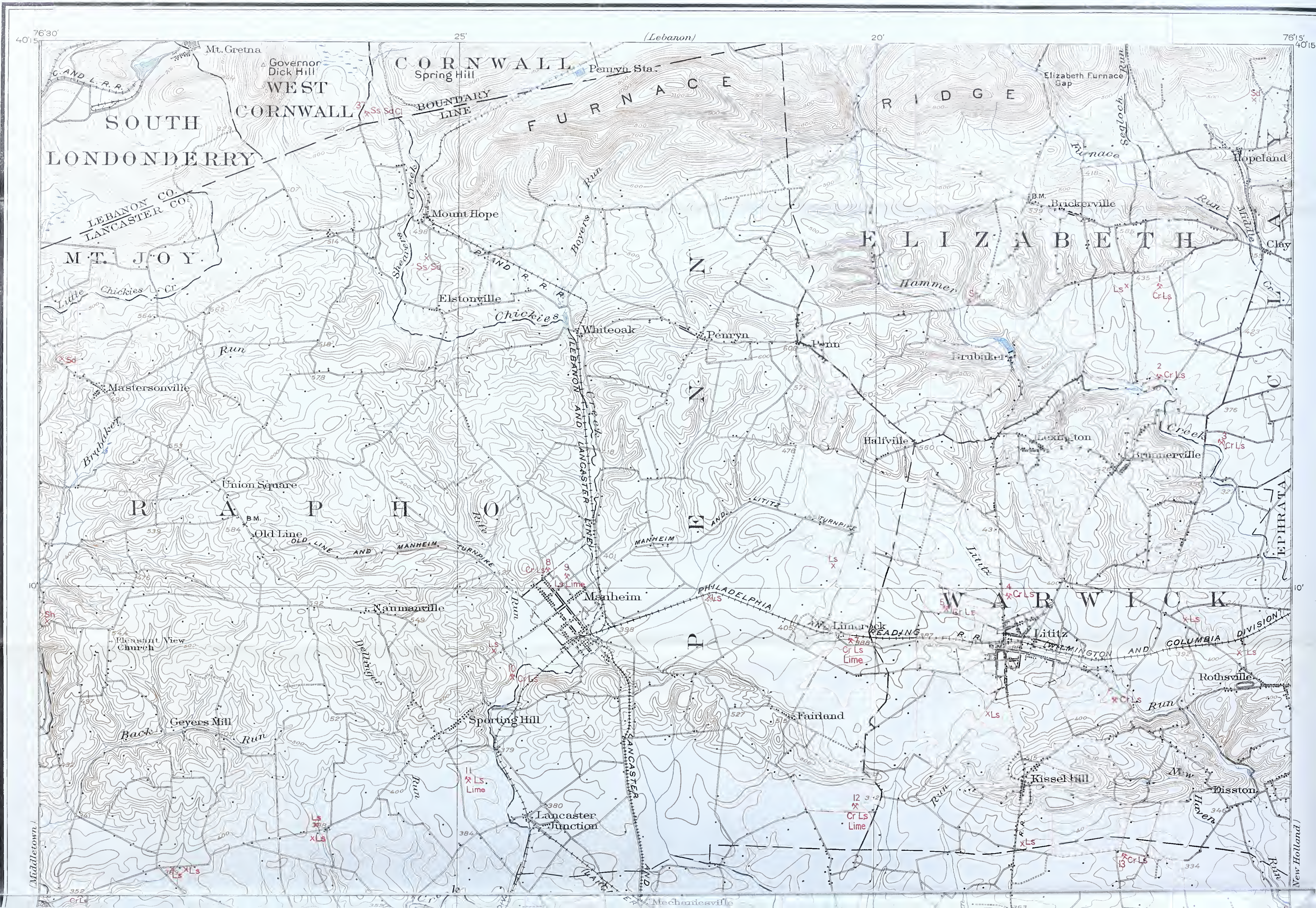
38. J. C. Budding Co.
39. Lancaster Brick Co.
40. C. Wise & Bros.

BUILDING STONE

41. A. R. Shaffer
42. W. B. Kendig
43. J D. Kendig

IRON ORE

44. Chestnut Hill
45. Heiss
46. Silver Spring
47. Copenheffer
48. [illegible]
49. R. Garbers
50. John Hertzler
51. [illegible]

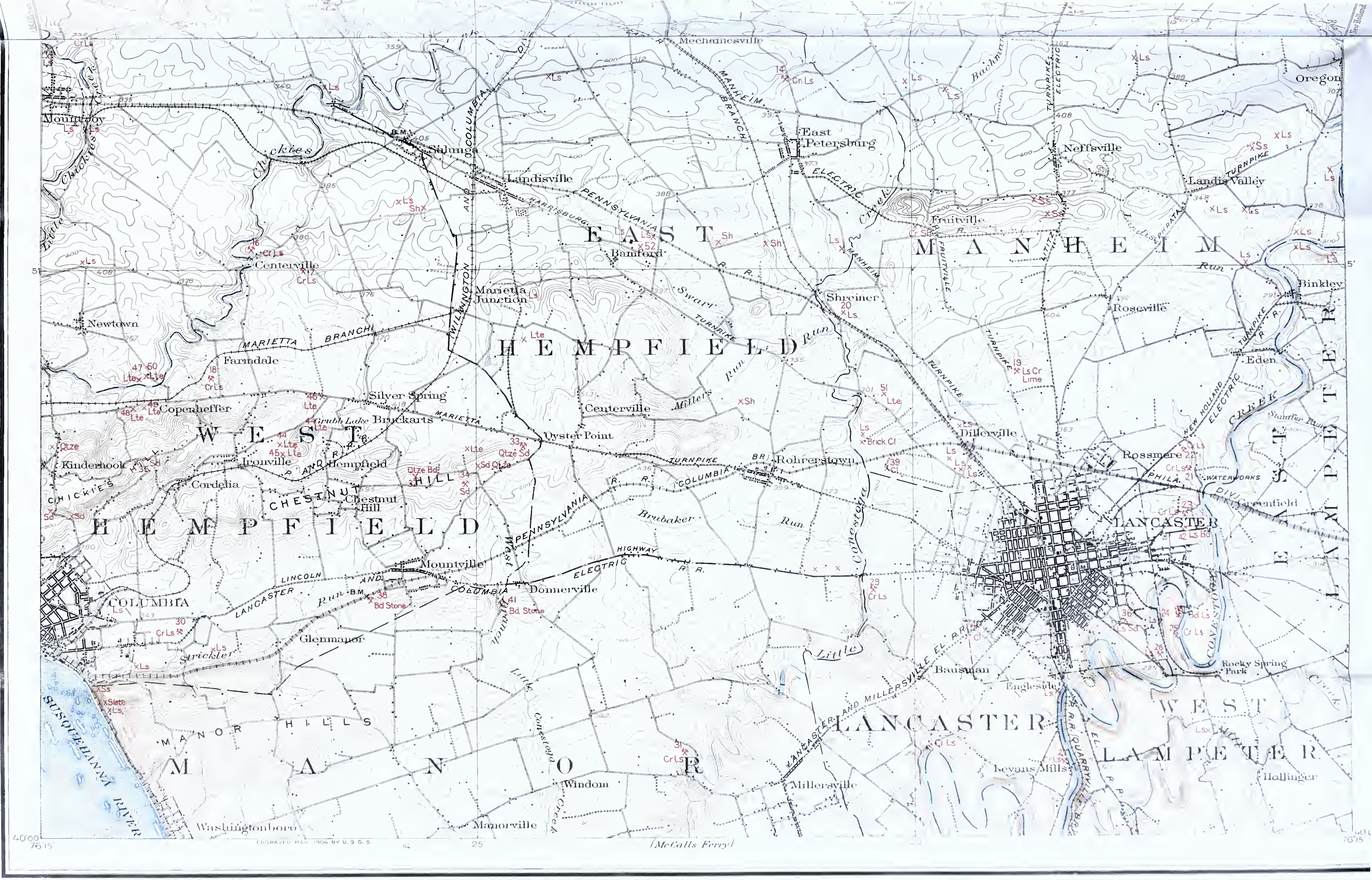


47. Copenheffer
48. Sheihs

50. John Hertzler
51. David Graybill

LEAD AND ZINC ORE

52. Bamford



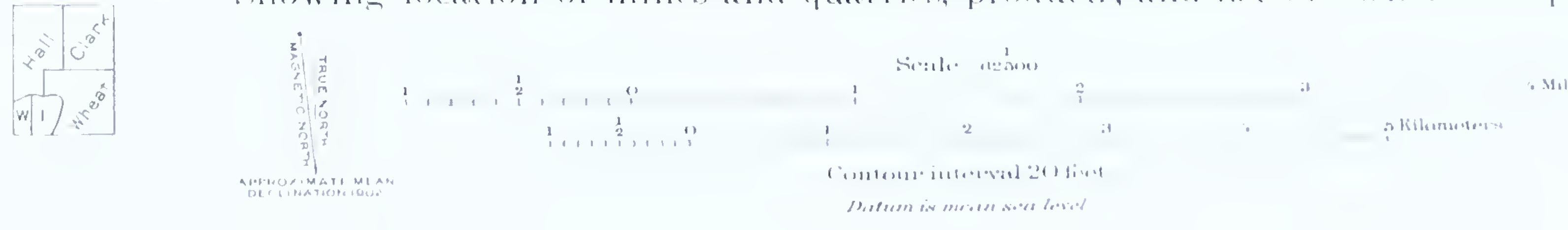
Base from U. S. Geological Survey topographic map of Lancaster Quadrangle, Pennsylvania
Surveyed in cooperation with the State of Pennsylvania in 1902

TOPOGRAPHIC MAP OF LANCASTER QUADRANGLE

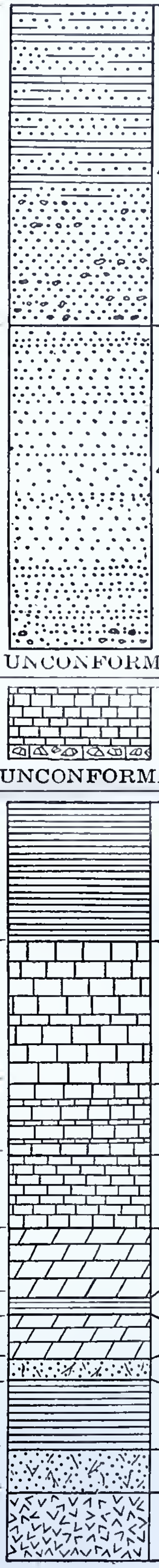
Showing location of mines and quarries, products, and list of owners or operators

A. HOEN & CO. BALTIMORE

Economic data by A. I. Jonas and G. W. Stose, 1926



Contour interval 20 feet
Datum is mean sea level



Periods or Systems	PENNSYLVANIA GEOLOGICAL SURVEY NAMES: Series	PENNSYLVANIA GEOLOGICAL SURVEY NAMES: Groups	U. S. GEOLOGICAL SURVEY NAMES: System		U. S. GEOLOGICAL SURVEY NAMES: Formation	Thickness. Feet	DESCRIPTION OF ROCKS
NINTH PERIOD or TRIASSIC SYSTEM	Upper Triassic or Newark	Gettysburg shale	TRIASSIC	Newark Group	Gettysburg shale with Elizabeth Furnace conglomerate member at the base.	4500'+	Top of formation not present in the quadrangle. Upper beds exposed, soft red sandstone and shale with some conglomerate beds. Lower bed, comprising Elizabeth Furnace conglomerate member, 0 to 2500 feet of heavy beds of hard red to gray sandstone and conglomerate with interbedded softer red sandstone and shale. Metamorphosed to hard rocks adjacent to intrusive diabase.
		New Oxford group			New Oxford formation (In northern part of quadrangle only)	4500'	Light-gray to grayish-yellow arkosic crumbly sandstone with interbedded thin red shale; some harder quartz-pebble conglomerate near base. Disintegrates to sand and gravel, which is sometimes dug for building sand. Metamorphosed to hard rocks adjacent to intrusive diabase.
					UNCONFORMABLE ON COCALICO SHALE		
THIRD PERIOD or ORDOVICIAN SYSTEM	Middle or Lower? Ordovician or Mohawk or Blount	Conestoga limestone	ORDOVICIAN		Conestoga limestone (In southern part only)	1000'±	Thin-bedded blue limestone generally closely folded, and gray granular limestone with slaty partings; coarse limestone conglomerate at the base.
					UNCONFORMABLE ON OLDER ROCKS DOWN TO VINTAGE DOLOMITE		
		Cocalico shale			Cocalico shale	2000'±	Bluish-black to dark-gray fissile shale; purple and green shale, probably in part volcanic ash and in places containing a thin white quartzite bed, near the base.
SECOND PERIOD or CANADIAN SYSTEM	Middle Canadian or Beekmantown	Beekmantown limestone			Beekmantown limestone	2000'±	Pure light-gray limestone, laminated magnesian limestone, and lenticular gray dolomite veined with calcite and quartz; contains some black chert.
	Lower Canadian or Ozark	Conococheague limestone	CAMBRIAN		Conococheague limestone	1000'±	Light-blue limestone banded with siliceous impurities, dolomite, and fine-grain white marble; contains cryptozoon reefs.
FIRST PERIOD or CAMBRIAN SYSTEM	Upper Cambrian	Elbrook limestone			Elbrook limestone	1000'±	Thin-bedded to shaly fine-grained, white to cream-colored marble and limestone with sericitic partings; weathers buff and earthy.
	Lower Cambrian	Tomstown group			Ledger dolomite	1000'±	Light-gray pure granular dolomite with some rough-weathering chert. Weathers to deep-red granular soil.
					Kinzers formation	200'	Dark shale below; blue banded limestone and white spotted marble above.
					Vintage dolomite	600'±	Dark-blue knotty dolomite with impure white marble at base.
		Harpers group			Antietam quartzite	300'±	Gray quartzite with granular ferruginous quartzite at the top.
					Harpers phyllite	1000'±	Light-gray phyllite and dark banded slate.
		Chickies group			Chickies quartzite	600'+	Massive white Scolithus-bearing quartzite and quartz schist with sericitic partings. Basal Hellam conglomerate member not exposed in quadrangle.
ALGONKIAN	Volcanic rocks		ALG.		Volcanic rocks		Altered basalt and rhyolite lavas. Not exposed in the quadrangle.

Fig. 2. Columnar section of the sedimentary rocks of the Lancaster quadrangle. Scale: 1 inch=3000 feet.

U. S. Geological Survey names are used in this report.

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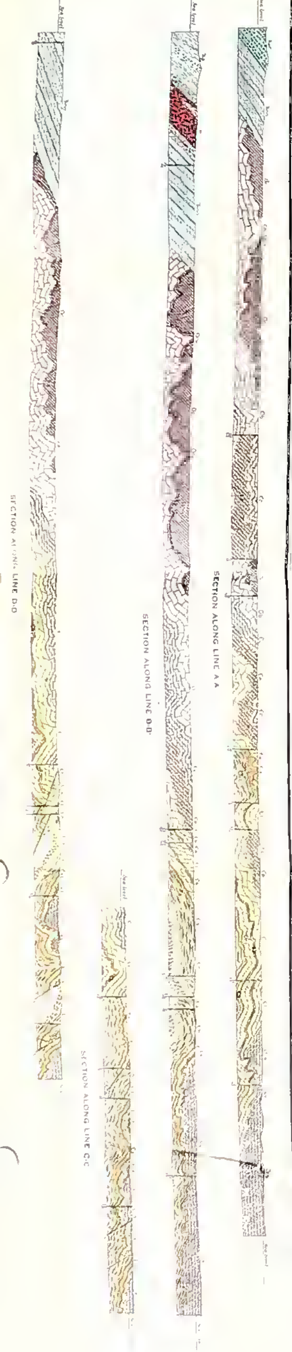
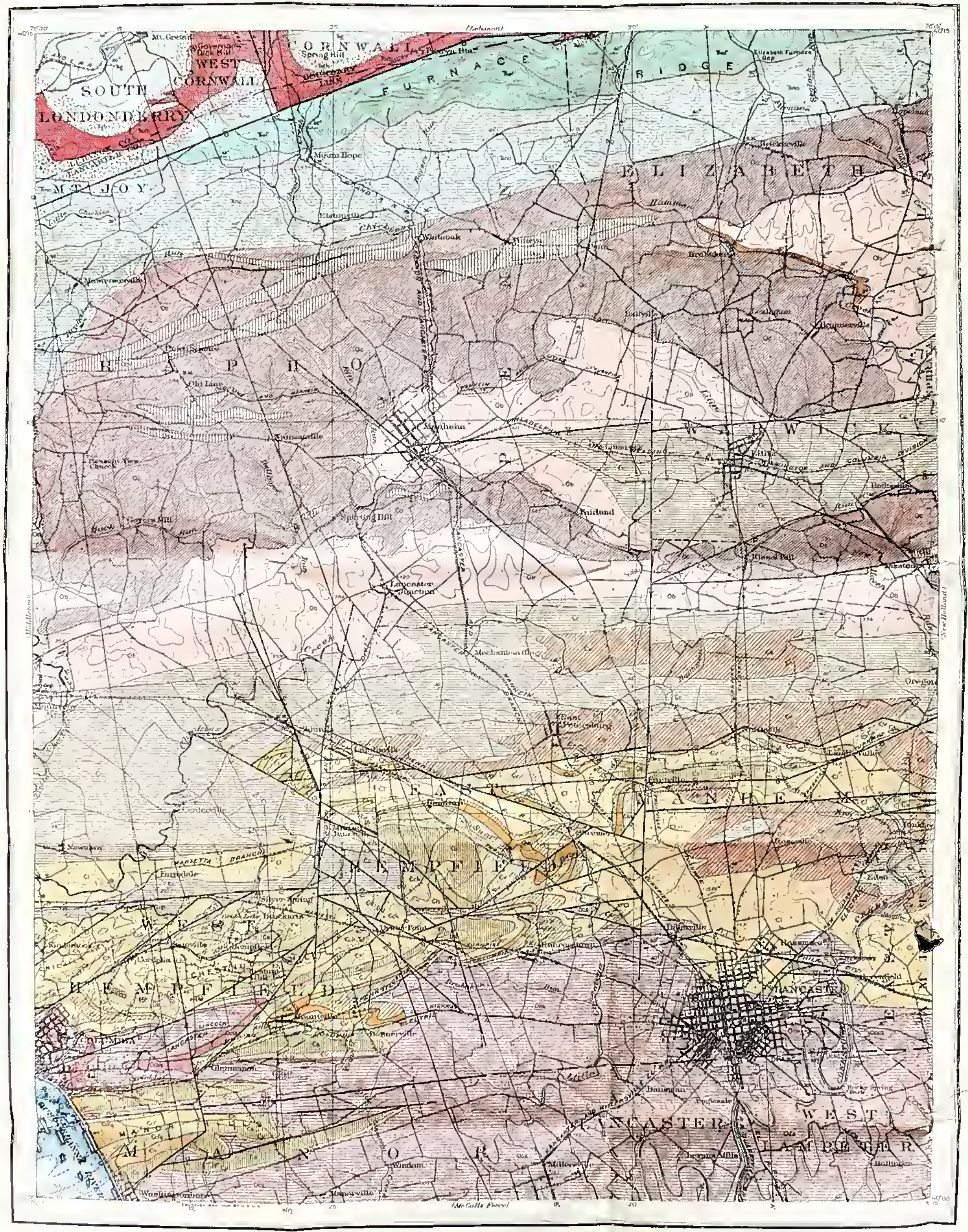
TOPOGRAPHIC AND GEOLOGIC
ATLAS OF PENNSYLVANIA
LANCASTER QUADRANGLE
SHEET 168 PLATE II





GEOLOGIC MAP OF LANCASTER QUADRANGLE

Base from U. S. Geological Survey topographic map of Lancaster Quadrangle, Pennsylvania. Surveyed in cooperation with the State of Pennsylvania in 1902

A. HOEN & CO. BALTIMORE

Geology by Anna I. Jonas, Penn. Top. and Geol. Survey and George W. Stose, U. S. Geological Survey. Surveyed in 1921-26

Scale $\frac{1}{62500}$
Miles
Kilometers
Contour interval 20 feet.
Datum is mean sea level.

EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY
Pleistocene

Qt
Lower terrace deposits
(sand, gravel, and large boulders on river terrace, 180 feet above sea level)

TERTIARY
Pliocene?

Th
High terrace deposits
(sand and gravel on river terrace, 180 to 280 feet above sea level)

TRIASSIC
Upper Triassic (Newark group)

Ŧg
Gettysburg shale
(chiefly soft red sandstone and shale, and crumbly conglomerate; baked to hard sandstone and conglomerate, Ŧgb, adjacent to intrusive diabase)

Ŧef
Elizabeth Furnace conglomerate member at base of Gettysburg shale
(hard red pebbly sandstone and conglomerate, forming high ridges, baked to hard conglomerate, Ŧeb, adjacent to intrusive diabase)

Ŧno
New Oxford formation
(red shale and sandstone interbedded with light-gray to yellow arkosic sandstone and crumbly conglomerate; baked to hard black porcelanite and light colored sandstone, Ŧnb, adjacent to intrusive diabase)

UNCONFORMITY

ORDOVICIAN
Lower and Middle Ordovician

Oc
Cocalico shale
(dark gray to bluish black shale, Trenton and probably younger age, hard purple and green volcanic? shale and thin quartzite, Ocv, near base; shaly earthy fossiliferous limestone with carbonaceous partings, Ocl, at base in places)

UNCONFORMITY

Ocn
Conestoga limestone
(thin-bedded blue limestone with argillaceous partings, closely folded, and veined with calcite; lower part probably of Chazy or Black River age, earthy banded sandstone and dark blue shale, Ocn, at base in places and sandy limestone weathering to sand, Ocsd, locally near base)

MARKED UNCONFORMITY
(overlaps formations down to Vintage dolomite)

Lower Ordovician

Ob
Beekmantown limestone
(pure blue limestone, laminated light blue magnesian limestone, and lumpy gray dolomite veined by calcite and quartz; some black chert; white marble at base; sparsely fossiliferous)

CAMBRIAN
Upper Cambrian (Ozarkian of Ulrich)

Cc
Conococheague limestone
(light-blue limestone banded with siliceous and argillaceous layers, dark and light-gray dolomite and cream to white fine-grained marble with impure laminations; contains reefs of cryptozoons in pure limestone, weathers to light sandy soil with shale fragments)

Middle Cambrian

Ce
Elbrook limestone
(thin-bedded to shaly impure white to cream-colored fine-grained marble, with sericite on partings; weathers to buff tripoli and light yellow soil)

Lower Cambrian

Cl
Ledger dolomite
(pure granular light-gray dolomite mottled with dark-gray, rough chert in middle part, weathers to deep red granular clay)

Ck
Cka
Kinzers formation
(lower part dark bluish to blue barely fossiliferous shale with highly fossiliferous earthy dolomite at base, Cka, overlain by blue limestone banded with impure layers, and white marble, spotted with irregular dolomite)

Cv
Vintage dolomite
(dark knotty dolomite with irregular banded impurities, and impure white marble at base, weathers to deep red clay)

Ca
Antietam quartzite
(light-gray banded quartzite and quartz schist and harder granular ferruginous fossiliferous sandy quartzite at top)

Ch
Harpers phyllite
(light-gray phyllite and dark sericite schist banded with white)

Cch
Chickies quartzite
([illegible] quartzite and quartz schist, thin bedded, sericitic, and granular with thin interbedded dark slate at top)

Chg
Cr
[illegible]
([illegible] with many [illegible] quartzite layers [illegible] thicker quartzite at top, Chg)

IGNEOUS ROCKS

LATE TRIASSIC

Ŧd
Diabase

CAMBRIAN ?

Pegmatite
(small dikes of pre-Cambrian(?) and post-orthoclase to Cambrian age [illegible])

Faults

T Thrust side of thrust fault
D Downthrown side of normal fault
U Upraised side of normal fault
→ Direction of movement of horizontal fault
Strike and dip of stratified rocks
Strike and dip of overturned beds
Strike of vertical beds
● Horizontal beds

ECONOMIC NOTE

Diabase quarried for road material and building stone. Sandstone beds in Gettysburg shale and Elizabeth Furnace conglomerate member used for road material and building stone; shale beds suitable for brick and tile manufacture.

New Oxford formation disintegrates to sand and gravel, dug for building purposes.

Cocalico shale suitable for brick clay.

Conestoga limestone extensively quarried for broken stone for road material and concrete and for building stone from sandy member; residual clay used for brick and the residual sand dug for building purposes.

Beekmantown limestone extensively quarried for building stone and broken stone, and formerly burned for field lime.

Conococheague and Elbrook limestones quarried for broken stone for road material.

Ledger dolomite suitable for dolomite lime, flux, and magnesium products.

Kinzers formation quarried in places for foundation stone and broken stone.

Vintage dolomite quarried for broken stone.

Antietam quartzite quarried for foundation stone and broken stone for road material and ballast, source of [illegible] ore deposits.

Harpers phyllite used locally for road material.

Chickies quartzite, [illegible] upper beds quarried chiefly for building [illegible] and as [illegible] stone.